REFINED RISK ASSESSMENT FOR THE KIRTLAND'S WARBLER POTENTIALLY EXPOSED TO MALATHION

DRAFT REPORT

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This report is the Refined Risk Assessment for the Kirtland's Warbler Potentially Exposed to Malathion and is consistent with the requirements of FIFRA. As such, it is not required to comply with 40CFR Part 160.

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EXECUTIVE SUMMARY

EPA recently released the draft endangered species Biological Evaluations for chlorpyrifos, diazinon and malathion (MAL). These biological evaluations are case studies and the lessons learned from them are envisioned to be helpful in shaping a national procedure for evaluating pesticide risks to species listed as threatened or endangered in the United States. As part of the case studies, EPA conducted refined risk assessments for 13 selected listed bird species including the Kirtland's warbler (*Setophaga kirtlandii*). The Kirtland's warbler is an endangered migratory species that nests exclusively in young jack pine stands in Michigan and Wisconsin, and winters in the Bahamas.

EPA's refined risk assessment for the Kirtland's warbler relied on the probabilistic TIM and MCnest models. Despite being probabilistic models, the models are highly conservative in many aspects with regard to determining risks of MAL to the Kirtland's warbler. For example, TIM assumes that Kirtland's warblers spend a significant portion of their foraging effort in and immediately adjacent to treated pastures during the breeding season. Decades of intense observation, however, have shown that warblers only forage in young jack pine forests during the breeding season. Other inputs used in TIM were also highly conservative. For example, EPA relied on the default value for fraction of pesticide retained from one hour to the next rather than the much shorter metabolism and elimination half-life based on the results of a registrant study. MCnest also has a number of overly conservative assumptions. For example, if the conservative estimate of chronic exposure from TIM exceeds the most sensitive avian reproduction NOEL, complete nest failure is assumed. Perhaps not surprisingly, given the combination of conservative assumptions in TIM and MCnest, the models predicted significant mortality (90 to 100% assuming high sensitivity, 15 to 35% assuming median sensitivity) and large impacts on reproductive fecundity for Kirtland's warblers annually for the pasture and other crops use patterns, the only two use patterns investigated. The reality is that the Kirtland's warbler has dramatically increased in abundance in recent decades despite widespread usage of malathion. This contradiction between EPA's model predictions and the real world indicates that a more scientifically defensible modeling effort is required for Kirtland's warblers potentially exposed to MAL.

Probabilistic, species-specific exposure models were developed to assess risks of MAL to Kirtland's warblers during the breeding season and during spring and fall migrations. The breeding area model simulates acute and chronic exposure and risk to each of 10,000 birds over a 60-day period following initial MAL application. The model is highly species-specific with regard to the foraging behavior of Kirtland's warblers during the breeding season. In addition, the model inputs relied on MAL-specific data when available. For the breeding area assessment, we simulated a representative use pattern for each of the seven crop classes that could be within 3 km of the breeding areas of Kirtland's warbler. In all cases, we assumed the maximum application rate and number of applications, and the minimum treatment interval.

The migration model simulates 10,000 birds during the course of their 12- to 23-day migration between their breeding area and the Bahamas. The model takes advantage of over a century of observations of when, where and for how long Kirtland's warblers forage in different habitats during the course of their migration. The data indicate that warblers only infrequently stopover in habitats that could be treated with MAL (e.g., apples in the Northeast, peaches in Georgia, oranges in Florida).

Using these more realistic and species-specific breeding area and migration models and inputs resulted in predictions of very low acute and chronic risk of MAL to Kirtland's warblers. Our refined risk assessments deliberately erred on the side of conservatism (e.g., assuming maximum applications rates, assuming 100% crop treatment in the breeding area model, use of most sensitive acute LC50 and chronic NOEL). Thus, the quantitative risk predictions should be considered as upper bounds. These results clearly indicate that the labeled use of malathion poses little risk to Kirtland's warblers.

Table of Contents

List of Tables

List of Figures

List of Appendices

1.0 INTRODUCTION

Under the *Federal Insecticide, Fungicide and Rodenticide Act*, the US Environmental Protection Agency (EPA) registers pesticides for use in the United States. Registration of a pesticide is an "action" under section 7(a)(2) of the *Endangered Species Act* (ESA). As such, EPA is required to ensure that pesticide registrations are unlikely to jeopardize threatened and endangered species or their critical habitat.

Malathion is currently undergoing registration review in the United States and is being used by the EPA as one of three case studies to develop a national procedure for evaluating risks to species listed as threatened or endangered in the United States. Like malathion, the other case studies involve organophosphate pesticides, i.e., chlorpyrifos and diazinon. As part of the case studies, EPA has highlighted the Kirtland's warbler (*Setophaga kirtlandii*) as a species of special concern. The Kirtland's warbler is an endangered species that has been observed in many states east of the Mississippi and in parts of Canada during migration (FWS, 2012). Nesting occurs in young jack pine stands in Michigan and Wisconsin, and wintering occurs in the Bahamas (FWS, 2012).

Herein, we describe a refined avian risk assessment specific to Kirtland's warbler. The report begins with a problem formulation to determine how and when Kirtland's warbler may be exposed to malathion and by what exposure routes during nesting and spring and fall migration. Chapters describing the refined exposure and effects analyses follow. The report concludes with a weight-of-evidence assessment for Kirtland's warbler potentially exposed to malathion.

2.0 PROBLEM FORMULATION

The goal of this problem formulation was to develop an analysis plan to guide the assessment of risks to the Kirtland's warbler. To accomplish the task, we review:

1. Kirtland's warbler life history and habitat information;
2. Currently labeled use patterns of malathion;
3. Physical and chemical properties of malathion;
4. Environmental fate and transportation of malathion;
5. Potential routes of exposure for the Kirtland's warbler; and
6. Toxicity of malathion to birds.

This information was used to identify protection goals, create a conceptual model, and develop an analysis plan that outlines the methods used to characterize risk to the Kirtland's warbler.

2.1 Kirtland's Warbler

The following subsections provide information on the listing status, description and taxonomy, distribution, habitat, feeding behavior, and life history of the Kirtland's warbler. This information was fundamental in developing an appropriate approach for assessing potential exposure of the Kirtland's warbler to malathion.

2.1.1 Species Listing Status

The United States Fish and Wildlife Service listed the Kirtland's warbler (*Setophaga kirtlandii*; *Dendroica kirtlandii*) as endangered on March 11, 1967 (FWS, 2012). The recovery priority of the Kirtland's warbler is 2C, indicating that there is a high degree of threat to the species but with a high potential for recovery (FWS, 2012). The primary objective of the recovery plan was to re-establish a self-sustaining Kirtland's warbler population maintained at over 1000 breeding pairs. The recovery goal was achieved in 2001, and the Fish and Wildlife Service (FWS) has recommended down listing the Kirtland's warbler to threatened status (FWS, 2012). The FWS has also recommended changing the recovery priority number for the Kirtland's warbler to 8, indicating that the species has a moderate degree of threat, but high recovery potential (FWS, 2012).

In 1951, only 432 singing males were found and breeding birds were confined to northern Lower Michigan (Mayfield, 1953). Record lows of 167 singing males were found in 1974 and 1987 (FWS, 2012). However, the population has since rebounded and 1828 singing males were identified in 2011 (MDNR, unpublished data, cited by FWS, 2012). In the 2012 census, 2090 singing males were identified (Bocetti et al., 2014). The population is maintained through intensive management of aged jack pine (*Pinus banksiana*) stands and active removal of brown-headed cowbirds (*Molothrus ater*). Availability of suitable habitat has increased 150% since 1979 (FWS, 2012).

In the past, the Kirtland's warbler breeding habitat (i.e., young jack pine forest) was severely reduced by fire suppression and subsequent forest succession. However, intensive land management has greatly offset the impacts of fewer wildfires and forest succession in recent years. Conflicting land uses on adjacent lands (e.g., residential development, golf courses, highway improvements) also threaten the species and reduce available nesting habitat. Other threats include wildfires during early growth of suitable habitat, drought, nest parasitism by cowbirds, and disease and insect outbreaks. During migration, reductions in the availability of food and suitable stopover habitat threaten the species. Threats to winter habitat include lack of protected lands, human development, altered fire regime, agriculture, climate change, drought, predators (cats), and invasive plant species (FWS, 2012).

2.1.2 Description and Taxonomy

The Kirtland's warbler is a large wood warbler, weighing 12-15 g and measuring 14 cm (Dunn and Garrett, 1997; Mayfield, 1960; Walkinshaw, 1983). It has bluish-gray underparts and its upperparts are heavily streaked with black. The throat, breast and belly are yellow with black streaking. The warbler has a white eye ring that is broken in front of and behind the eye. Males are brighter in color than females, whereas juveniles are predominantly grayish-brown (FWS, 2012).

The Kirtland's warbler belongs to the Order Passeriformes and Family Parulidae. In 1852, the species was described as *Sylvicola kirtlandii* (Baird, 1972), but has since been reclassified to *Setophaga kirtlandii.* The Kirtland's warbler is also classified as *Dendroica kirtlandii*. The species is closely related to the American redstart (*S. ruticulla*) and the Cape May warbler (*S. tigrina*) (Chesser et al., 2011).

2.1.3 Distribution

The Kirtland's warbler has a limited geographical distribution (Figure 2-1). The wintering range is restricted to the Bahamas archipelago, and the breeding range is limited to parts of Michigan, Wisconsin and Ontario (FWS, 2012). Adults return to the same breeding grounds annually (Berger and Radabaugh, 1968), but yearlings tend to disperse to new nesting areas (Ryel, 1979).

More than 86% of the Kirtland's warbler breeding range is located in only five counties in northern Lower Michigan; Ogemaw, Crawford, Oscoda, Alcona, and Iosco (MDNR, unpublished data, cited by FWS, 2012). Warblers are also found in southern Ontario, Wisconsin, and the Upper Peninsula of Michigan (Aird, 1989). However, only 3% of the male population is found outside of Lower Michigan (MDNR, unpublished data, cited by FWS, 2012). In Wisconsin, nesting pairs have been found in Adams and Marinette Counties.

Figure 2-1 Breeding, migration and winter ranges of the Kirtland's warbler (Bocetti et al., 2014)

Territories are on average 13.6 hectares in size (Huber et al., 2013), though Walkinshaw (1983) suggested a smaller range in territory size (4.12 to 8.48 ha) when habitats are favorable. The nest is typically placed halfway between the center of the territory and the edge (Bocetti, 1994). Territories do not overlap, but often occur in clusters so that a male can hear the call of its neighbor (Mayfield, 1960; Walkinshaw, 1983; Bocetti, 1994; Rockwell, 2013).

Eleuthera Island in the Bahamas archipelago supports the largest wintering population of Kirtland's warbler (Ewert et al., 2009). Spring migration begins in mid-April to early May (Mayfield, 1992), and takes approximately 12 to 23 days to complete (Ewert et al., 2012). Males arrive on the breeding grounds mid-May, with females arriving a week later (Mayfield, 1960). Hatchlings begin fall migration in mid-August to early September, whereas adults generally migrate in late September (Sykes et al., 1989). The birds tend to migrate alone, rather than in flocks (Sykes et al., 1989), and have been observed in many states east of the Mississippi from the breeding grounds to Florida (Petrucha et al., 2013). Sightings in the New England area are rare (Petrucha et al., 2013).

2.1.4 Habitat

Kirtland's warblers live in jack pine (*Pinus banksiana*) forests on glacial outwash plains in northern Lower Michigan, Upper Peninsula Michigan, Wisconsin, and Ontario. They prefer jack pine stands that are 5 to 23 years old and at least 12 ha acres in size (Donner et al., 2008). Younger trees are preferred because the canopy is sufficiently open to maintain low branches for feeding from trees and for nest protection from predators (FWS, 1985). Trees over 20 feet (~7 m) in height are not desirable. Nesting occurs in stands with at least 20% canopy cover (Probst, 1988) and trees 1.7-5.0 m in height (Probst and Weinrich, 1993). Stands are located on dry, well-drained, and nutrient-poor glacial outwash sands, and may also include red pine (*Pinus resinosa*) and pin oak (*Quercus palustris*) (Mayfield, 1953; Orr, 1975; FWS, 1985; Fussman, 1997; Anich et al., 2011). Kirtland's warblers are most often found in jack pine plantations maintained for the species or for timber. Probst et al. (2003) found that as habitat management increased, the proportion of warblers in natural wildlife habitat decreased from 76% in 1984 to 18% in 2000, despite a significant increase in overall population size. Therefore, extensive habitat management has greatly helped to increase the population.

The Kirtland's warbler is closely associated with Grayling sand soils that support the jack pine, and have been documented nesting in adjacent Graycalm, Deer Park, Rubicon, and Croswell sands (FWS, 1985). The breeding area has been documented as "unfavorable growing conditions" because of its inland, relatively high elevation location and late-spring/early-fall frost occurrences (Kashian et al., 2003).

Optimal habitat for the Kirtland's warbler includes the following (Probst, 1988; Probst and Weinrich, 1993; FWS, 1985, 2012):

- 8 to 15-year old jack pines regenerated after wildfires;
- 35 to 65% canopy cover;

- >7500 stems/ha;
- Stands of 200 acres (80.9 ha) or more;
- Poor quality and well-drained soils that reduce risk of nest flooding; and
- Low shrubs for nest cover.

Wintering habitat consists of early successional shrublands with dense, low broadleaf scrub of varied foliage layers (Challinor, 1962; Mayfield, 1972, 1992, 1996; Radabaugh, 1974; Lee et al., 1997; Haney et al., 1998; Sykes and Clench, 1998; Wunderle et al., 2007, 2010). Habitats are small and dominated by dense, fruit-bearing shrubs, including snowberry, wild sage, and black torch (Wunderle et al., 2010).

Less is known regarding the migratory habitats of Kirtland's warblers. They have been observed in residential, woodland, scrub, park, and orchard habitats (FWS, 2012). Over 92% of recorded migrants were observed as lone birds (Petrucha et al., 2013). Birds tend to be particularly attracted to dense vegetation that is approximately 1.5 m in height (Stevenson and Anderson, 1994). Stopovers last 1.23 days on average and birds are normally observed foraging in low shrub-scrub vegetation dominated by woody plants (Petrucha et al., 2013). Over 80% of documented migrant warblers (n=184) were found in shrub/scrub habitat, which is characterized as habitat dominated by woody plants ≤20 feet (~7 m) in height and similar in structure to breeding habitat (Petrucha et al., 2013). An additional 10% of individuals were found in residential areas dominated by private yards (Petrucha et al., 2013). Less than 4% of migrating individuals were found in each of parks, woodlands (closed canopy forest), and orchards (fruit tree plantations; spring only), and only one individual has been observed in open land (Petrucha et al., 2013). In the fall, individuals were only found in shrub/scrub, residential, and park habitats. No migrating individuals have been recorded in agricultural land (Petrucha et al., 2013).

Spring migration occurs in a broad band east of the Mississippi River and mostly between 80 and 90°W longitude. The mean longitude of fall migrants was 82.9°W and they were less geographically concentrated than spring migrants (Petrucha et al., 2013). Foraging was the behavior most often observed during migration stopovers, and occurred primarily in shrub/scrub habitat (<7 m), but also on the ground and in the canopy (Petrucha et al., 2013).

2.1.5 Feeding Behavior

Kirtland's warblers are primarily insectivorous, foraging by gleaning insects from pine needles, leaves and ground cover, as well as catching flying insects on the wing (FWS, 2012). Foraging primarily occurs from low branches of jack pines, and to a lesser extent from oak and ground vegetation (Fussman, 1997).

Dietary items include larvae, moths, flies, beetles, grasshoppers, ants, aphids, spittlebugs, blueberries, pine needles, and pitch from twigs and jack pine (Mayfield, 1960; Walkinshaw, 1983; Fussman, 1997). Spittlebugs, ants, and blueberries comprise the majority of the warbler diet from July to September (DeLoria-Sheffield et al., 2001). Of 202 fecal samples analyzed, 61% contained spittlebugs and aphids, 45% contained ants and wasps, 42% blueberries, 25% beetles, and 22% moth larvae (DeLoria-Sheffield et al., 2001).

On the wintering grounds, primary food items include snowberry, wild sage and black torch fruits, and to a lesser extent, arthropods (Wunderle et al., 2010). Migratory foraging occurs in low shrub-scrub vegetation and birds eat mostly invertebrates and some fruits (Petrucha et al., 2013).

2.1.6 Life History

Breeding occurs in Michigan and Wisconsin during the summer months. Both monogamous and polygynous males exist and may change breeding tactics from year to year (Bocetti, 1994). However, initial pair bonds generally form within one week of arrival on the breeding grounds (Mayfield, 1992). Breeding occurs in the first year (Walkinshaw, 1983).

Females build nests on the ground in areas concealed by grasses and low-lying vegetation, and generally avoid nesting near territory edges (Bocetti, 1994). Nests are built from course sedge, red pine needles, blueberry twigs, and other woody plants. Five eggs are generally laid in the first clutch, starting on the day of nest completion, and four eggs are laid in replacement and second clutches (Mayfield, 1960). The first egg is laid around June 1st (Rockwell, 2010). The average clutch is 4.58 eggs (Rockwell, 2013). Incubation is performed by the female and lasts 13-15 days (Walkinshaw, 1983). The female spends all night and almost all day (84%) on the nest (Mayfield, 1960). Fledging occurs 9.4 days on average after hatching (Mayfield, 1992).

2.2 Malathion Use Patterns

Malathion (2-[(dimethoxyphosphorothioyl)sulfanyl]butanedioate) is an organophosphate insecticide that provides broad spectrum control of insects in agriculture, ornamental nurseries, pastures, and rangelands. Malathion is also applied for residential outdoor use, for building perimeters, regional pest eradication/suppression programs, and to control adult mosquitoes, biting midges, and flies of public health and veterinary importance.

Malathion is registered for a wide variety of crops, including alfalfa, apples, corn, dry beans, potatoes, and wheat. For additional information on malathion use patterns, see Appendix A.

Malathion is applied to foliage, soil (as a spot or perimeter treatment), or dormant trees. Application can occur post-plant or during the dormant season using fixed wing and rotary aircraft, truck-mounted fogger, ground boom, and hand-held sprayer. Maximum single application rates range from 0.5 to 7.5 lb ai/A for crops. Multiple applications are allowed for the majority of use patterns, excluding the two highest (4.5 and 7.5 lb ai/A) application rates for citrus.

2.3 Fate, Transport and Degradates of Malathion

The major route of malathion transformation is aerobic biodegradation in soils and sediments (Saxena, 1988 [MRID 47834301]; Blumhorst, 1990 [MRID 41721701]; Knoch, 2001b [MRID 46769501]; Nixon, 1995 [MRID 43868601]). The rapid degradation of malathion in soil leaves little malathion available for uptake by plants (Wootton and Johnson, 1993 [MRID 42785501]). Malathion is not expected to partition to air (Cheminova A/S, 1988 [MRID 40966603]).

The major hydrolysis transformation products of malathion in alkaline soil are malathion dicarboxylic acid (MDCA) and malathion monocarboxylic acid (MMCA) (Saxena, 1988 [MRID 47834301]; Blumhorst, 1990 [MRID 41721701]; Knoch, 2001b [MRID 46769501]). Because these compounds are significantly less toxic than malathion, neither of these compounds are expected to significantly contribute to the ecological risk of Kirtland's warblers compared to the parent compound.

Malaoxon (MALO; 2-(dimethoxyphosphorylsulfanyl)butanedioate) is formed by metabolic processes in vivo. It is rapidly degraded, with a half-life shorter than one day. The oxon is slightly more toxic than the parent compound to some species, but poses little risk because it is formed in very small quantities in the terrestrial environment and is rapidly degraded (Rodgers, 2002 [MRID 48153114]; Gallagher et al., 2002a [MRID 48153104]; Stafford, 2011a; b [MRID 48571805; 48571806]; Hubbard and Beavers, 2012a-c [MRID 48963305; 48963307; 48963306]; Hubbard et al., 2012a-e [MRID 48963303; 48963301; 49024601; 48963302; 48963304]; Gallagher et al., 2002b [MRID 48153105]; Gallagher et al., 2003 [MRID 48153106]; Hiler, 2012 [MRID 48903601]).

For the reasons cited above, MDCA, MMCA, and malaoxon will not be considered in this assessment.

A study involving white leghorn chickens was initiated to evaluate the fate of [2,3-^{14}C]-malathion in birds (Cannon et al., 1993 [MRID 42715401]). Four birds (and four controls) were treated for four days with 3.8 mg ai/bird radio-labelled malathion administered orally via capsules, and sacrificed for tissue analysis 24 hours following the last dose. Radioactivity was measured in kidneys, liver, heart, white meat, dark meat, fat, and skin. On average, 29% of the daily dose was excreted daily in feces as malathion through the study period. Radiolabelled-malathion was not detected in any of the organs (method detection limit was ≤ 0.01 mg ai/kg ww). Similarly, malathion metabolites (malaoxon, MMCA, MDCA, and desmethyl malathion) were not detected, or were detected at levels ≤ 0.01 mg ai/kg ww.

2.4 Routes of Exposure for Kirtland's Warbler

Malathion is registered for use post-plant and during the dormant season (Appendix A). It can be applied by fixed wing and rotary aircraft, truck-mounted fogger, ground boom, irrigation, and hand-held sprayer (Appendix A). As a result, various crop stages can be treated. Following application, malathion residues have been detected in soil, foliage, invertebrates, and standing water (Habig, 2011 [MRID 48409301]; Knäbe, 2004 [MRID 46525902]; Hiler and Manella, 2012 [MRID 48986601]). Spray drift and runoff can lead to malathion residues on foliage and in water bodies adjacent to the treated field. Kirtland's warblers are highly unlikely to be exposed to malathion by direct contact in the treated area because of their strong preference for young jack pine forests and similar habitats (Probst, 1988; Probst and Weinrich, 1993; FWS, 1985, 2012). They could, however, be exposed to contaminated dietary items and drinking water in their preferred habitats if those habitats are close to treated areas.

Exposure to malathion through inhalation and dermal contact are potential routes of exposure for Kirtland's warblers following spray drift to their habitats.

Based on an analysis with the EPA (2010a) Screening Tool for Inhalation Risk (STIR), version 1.0, we determined that inhalation of malathion is not a significant exposure pathway for birds. In the STIR analysis, airblast application at the highest permitted single application rate (i.e., 7.5 lb ai/A for citrus) and a vapor pressure of 4.0 x10^{-5} mm Hg (at 30°C; Cheminova A/S, 1988 [MRID 40966603]) were assumed. The predicted exposure concentration was compared to the lowest oral LD50 for birds (136 mg ai/kg bw for ring-necked pheasant; Hubbard and Beavers, 2012a [MRID 78963305]; 836 g body weight females) and an inhalation LD50 of >5.2 mg ai/kg bw determined for rats (MRID 00159878). The model concluded that inhalation "exposure is not likely significant" for birds exposed to malathion on treated areas immediately after application at the highest permitted rate. Inhalation will therefore not be considered in this assessment.

A similar analysis was performed with the EPA (2010b) Screening Imbibition Program (SIP) tool, version 1.0, to determine if drinking water alone posed significant risks to birds. The SIP tool was parameterized using the water solubility of malathion (145 mg/L; Cheminova A/S, 1988 [MRID 40966603]), LD50 for birds (136 mg ai/kg bw for ring-necked pheasant, Hubbard and Beavers, 2012c [MRID 48963305]), average female body weight of 836 g, and the lowest chronic NOEC for birds (110 mg ai/kg diet, Beavers et al., 1995 [MRID 43501501]). Using the most conservative effects metrics available for malathion, SIP determined that chronic exposure to drinking water was a potential concern for birds. However, given the rapid rates of degradation (0.3 to 3.3 days; Blumhorst, 1991 [MRID 41721601]; Knoch, 2001a [MRID 46769502]; Hiler and Mannella, 2012 [MRID 48906401]) and dissipation (0.8 to 2.3 days; Ebke, 2002 [MRID 46525901]) of malathion in water, exposure via drinking water is likely to be minimal. Further, Kirtland's warblers obtain all or nearly all of their drinking water through their diet and have never been observed drinking water (Mayfield, 1960). Thus, drinking water as an exposure route is not considered further for Kirtland's warblers potentially exposed to malathion

Although malathion is a non-ionic, organic chemical and may reach aquatic habitats through spray drift and runoff, the log Kow of malathion is 2.75 (Mangels, 1987 [MRID 40944108]). Therefore, malathion has a low potential for bioaccumulation and the KABAM model need not be run (EPA, 2009b).

For the Kirtland's warbler, exposure in treated row crops or orchards is highly unlikely during the breeding season because the species has a very restricted habitat and is only found in young jack pine forests or in low scrub-shrub vegetation. Therefore, significant exposure during the breeding season could only occur through spray drift contamination of food items (insects and fruit).

The vast majority of sightings of Kirtland's warblers during spring and fall migrations have been in scrub-shrub habitats. Of the documented 187 sightings of Kirtland's warblers during spring and fall migrations where stopover habitats were reported, only three were in habitats that could be treated with malathion, i.e., orchards (Petrucha et al., 2013). The three sightings in orchards all occurred in the spring over 100 years ago (1895 near Wabash, Indiana; 1899 in Morgan Park, Chicago; 1900 near Oberlin, Ohio) (see Appendix 1 in Petrucha et al., 2013). For this assessment, exposure to contaminated dietary items in recently treated orchards will be considered for migrating Kirtland's warblers.

2.5 Mode of Action and Toxicity

Malathion is a contact organophosphorus pesticide, with stomach and respiratory action, and is used to kill a broad range of insects and mites. Organophosphate chemicals such as malathion bind to and inhibit the functionality of acetylcholinesterase (AChE) in the central and peripheral nervous systems. Although the inhibition of AChE does not necessarily have adverse effects, it may result in a temporary effect if over-exposure leads to the build-up of enough of the neurotransmitter acetylcholine (ACh) at cholinergic nerve endings, causing continual nerve stimulation (Namba, 1971; EPA, 2009a).

2.5.1 Direct Effects

All available toxicity studies were reviewed and rated using study evaluation criteria developed by Breton et al. (2014a).

Four acceptable acute oral LD50 studies for birds are available. In all studies, birds were dosed once with malathion by oral gavage in corn oil and observed for 14 days. The ring-necked pheasant (*Phasianus colchicus*) and northern bobwhite (*Colinus virginianus*) were the most sensitive species, with LD50s of 136 mg ai/kg bw and 345 mg ai/kg bw, respectively (Hubbard and Beavers, 2012c [MRID 48963305]; Rodgers, 2002 [MRID 48153114]). The least sensitive species were the mallard duck (*Anas platyrhynchos*) and yellow canary (*Serinus canaria*), with LD50s of >2250 and >2400 mg ai/kg bw for the two species, respectively (Hubbard and Beavers, 2012a [MRID 48963307]; Stafford, 2011 [MRID 48571805]). Based on these data, EPA classified malathion as having low to moderate acute toxicity to avian species (EPA 2009a).

There are three acceptable and no supplemental acute dietary studies available for birds exposed to malathion. Gallagher et al. (2003a [MRID 48153106]) exposed northern bobwhite to malathion in the diet for five days and reported an acute dietary LC50 of 2,022 mg ai/kg diet. Intrinsik converted the dietary concentration to a dose of approximately 555 mg ai/kg bw/d, based on the mean reported bird weights and food intake rates from the study. The second dietary study was conducted using the mallard duck (Hubbard et al., 2012a [MRID 48963303]). The reported acute dietary LC50 was >5,620 mg ai/kg diet (>2349 mg ai/kg bw/d; author reported) for a 5-day exposure period. The third acceptable dietary study was conducted using the ring-necked pheasant, which was exposed to malathion in the diet for five days (Hubbard et al., 2012b [MRID 48963301]). The reported acute dietary LC50 was 2,514 mg ai/kg diet (1102 mg ai/kg bw/d; author reported). Based on these data, EPA classifies malathion as being only slightly toxic to avian species by the dietary route (EPA, 2009a).

There is one acceptable and one supplemental chronic avian study available. Northern bobwhites were exposed for 21 weeks to malathion in the diet (Beavers et al., 1995 [MRID 43501501]). The NOEL and LOEL for reduced egg shell thickness, number of eggs laid, and viability were 350 and 1,200 mg ai/kg diet, respectively. The NOEL for regressed ovaries and reduced egg hatch was 110 mg ai/kg diet (12.6 mg ai/kg bw/d), with a corresponding LOEL of 350 mg ai/kg diet (Beavers et al., 1995 [MRID 43501501]). Pederson and Fletcher (1993 [MRID 42782101]) exposed mallard ducks to malathion for 20 weeks and found a NOEL and LOEL of 1,200 and 2,400 mg ai/kg diet, respectively, for growth, egg production and egg shell thickness. Based on these data, EPA concluded that chronic exposure to malathion shows moderate toxicity to terrestrial avian species and low toxicity to waterfowl species (EPA, 2009a).

Oral gavage exposure does not accurately reflect exposure of birds and mammals in the field. In an oral gavage study, the effects of natural dietary matrices, feeding patterns, metabolism and elimination throughout the day are not accounted for. Therefore, daily dietary LD50s are generally much higher than oral gavage LD50s.

2.5.2 Indirect Effects via Reduction in Prey Items

Kirtland's warblers may be indirectly affected by malathion application via a reduction in availability of insects in young jack pine forests. Jack pine forests are usually located some distance from agricultural lands, so exposure would only occur via spray drift. Availability of fruits consumed by Kirtland's warblers (e.g., blueberries) would not be affected by malathion because it is essentially non-toxic to plants (EPA, 2009a; 2010c) and habitats of Kirtland's warbler are generally located well away from treated areas.

A trial in an alfalfa field was used to estimate the off-crop effect of malathion on non-target arthropods (Knäbe, 2003 [MRID 49086408]). Malathion (CHA 3110) was applied once at a rate of 0.037 lb ai/A or six times at a rate of 0.053 lb ai/A using application intervals of 8, 10, 10, 11 and 10 days. The 0.037 lb ai/A and 0.053 lb ai/A treatments were calculated based on recommended field application rates of 1.34 lb ai/A and 1.93 lb ai/A, respectively, assuming a 1 m drift rate of 2.77%. Significant reductions in the Heteroptera community were observed four days after the second and sixth applications, but had returned to normal by subsequent sampling times. No other significant reductions were found and the authors determined that malathion did not significantly reduce non-target arthropods.

A similar field trial to the one summarized above examined the off-crop effects of malathion applied to an apple orchard on non-target arthropods (Müther, 2003 [MRID 49086409]). Malathion (CHA 3110) was applied three times to apple orchards using two-week retreatment intervals. Application rates were calculated from 10 and 20 m drift rates, which corresponded to 3.6 and 1.09% of the field rates, respectively. The field rate was 1.6 lb ai/A and the nominal application rates were 0.018 and 0.058 lb ai/A for the 10 and 20 m drift rates, respectively. No reductions in spider, insect or predatory mite populations were observed beyond natural variation. Thus, no significant off-crop effects were observed on non-target arthropod populations.

Giles (1970 [MRID 00058820]) studied the effects of malathion on arthropods and insects in a small forested watershed over a two-year period. In 1961, tracer plot studies were conducted to develop techniques for use of the radionuclide tracer method. Malathion-S^{35} was applied to two 0.04 ha (0.1 A) plots on August 29th, 1961 at a rate of 0.81 kg/ha (0.73 lb/A), using a backpack ground sprayer and two other plots were included as carrier and untreated controls. In 1962, malathion-S^{35} (0.81 kg/ha or 0.73 lb/A) was aerially applied to one of two adjoining eight hectare (roughly 20 acres) forested watersheds. On May 15th, 1962 the plane crashed at the end of the first swath and most of the malathion in the tank was confined to the airplane and the crash site. A second flight occurred on May 25th, 1962 and malathion application was completed.

Soil arthropods were collected using nylon bags filled with leaf litter and cryptozoan boards. Invertebrates of several classes were collected using nylon bags (i.e., Insecta, Siplopoda, Chilopoda, Acarina, Pauropoda, Araneida, Symphyla, Phalangida and Pseudoscorpionida). However, only data for oribatid and nonoribatid mites (Acarina) and Collembolans (Insecta), which made up 75 to 96% of soil invertebrates collected, were analyzed. Decreases in the mite population were observed in the treated watershed following the aborted malathion application on May 15th, 1962 and the second application on May 25th, 1962. Collembolan populations were reduced by 75% in the treated watershed following the May 15th application and also decreased after the May 25th application. Recovery of both populations occurred within approximately two weeks. Several invertebrate taxa were also observed when using cryptozoan boards as a sampling device, but only Collembola, Thysanura and arachnids were present in large enough numbers to allow for interpretation of changes over time. Again, Collembolan populations were significantly reduced in the treated watershed after malathion application. They had not recovered three months after treatment, but the author suggested that this could have been due to a prolonged dry period. Thysanuran populations were slightly suppressed following malathion treatment, but populations were too variable to make a conclusion with any certainty. No significant changes were observed for beetles, centipedes, millipedes, spiders, crickets, or isopods.

Other insects and arthropods were sampled using sweep nets, light traps, molasses traps, suspended sticky boards, tree trunk sticky bands, catch cloths and random collecting. The results from random sampling indicated that 12 insect families were not represented using the other sampling methods. Reductions in the numbers of arthropods sampled using sweep nets were observed in the treated watershed following malathion application. Cantharidae, Phalaeniidae, Microlepidoptera, Tipulidae and Cecidomyiidae were also observed following malathion treatment. Using molasses traps in the 1961 tracer plot studies, reductions in arthropod diversity were observed on treated plots in comparison to control plots. These differences persisted through 17 days, after which the molasses traps were removed. In the watershed study conducted in 1962, Nitidulidae was the most highly represented family from molasses trap sampling. Nitidulidae populations decreased after malathion application in both the untreated and treated watersheds. Twenty-one days after spraying, populations rapidly increased in the treated watershed, but not the control watershed. The results from sampling with sticky boards were difficult to interpret due to low arthropod counts prior to malathion application and large increases in populations after treatment. Counts from individual taxa were low and variable and conclusions regarding changes between watersheds before and after malathion application could not be made with any confidence. Results obtained from insect sampling with catch cloths indicated that reductions in insect populations were not correlated with radioactivity measurements made on glass discs. Measures of the malathion levels applied using discs may have been inaccurate, insects coming into contact with the application could have moved more than 61 m (i.e., distance between sampling stations) before dying, or both scenarios may have occurred to account for the lack of correlation.

Spiny-bellied spider (*Micrathena gracilis*) populations were estimated using web counts. Nearly identical populations and web activity were observed in treated and control areas after malathion application. Similar spider populations had previously been observed in both watersheds in 1961. Furthermore, large numbers of live spiders were observed in catch cloths after malathion application, indicating that malathion had little to no effect on spiders. Overall, soil arthropod populations were affected for a short period of time, but subsequently recovered. Insect abundance recovered rapidly, but species composition was affected by malathion exposure. Earthworms, snails and spiders were unaffected by malathion treatment.

These studies suggest that reductions in the prey items of Kirtland's warblers are likely to be negligible, and that rapid recovery of any affected populations is likely to occur. Therefore, risk to Kirtland's warbler due to a decrease in prey items is likely to be minimal.

2.5.3 Indirect Effects via Reduction in Habitat

EPA (2010c) previously concluded that malathion is non-toxic to terrestrial plants. Although significantly reduced dry weight was noted at 2.4 lb ai/A for cabbage, seedling emergence and vegetative vigor studies indicated no effects at treatment rates up to and including 4.7 lb ai/A for the majority of species tested, (Sindermann et al., 2013 [MRID 49076002]). Given that young jack pine habitats could only be exposed to malathion via spray drift and at rates well below those permitted on the malathion label, risks to habitats of the Kirtland's warbler are negligible.

Indirect effects to Kirtland's warblers from a reduction in suitable habitat due to malathion use are not considered further.

2.6 Protection Goals

Protection goals describe the overall aim of risk-based decision making and are used as the basis for defining assessment endpoints. In turn, assessment endpoints are ecological characteristics deemed important to evaluate and protect. They guide the assessment by providing a basis for assessing potential risks to receptors. Factors considered in selecting assessment endpoints include mode of action, potential exposure pathways, and sensitivity of ecological receptors. Assessment endpoints can be general (e.g., preservation of jack pine forest habitat) or specific (e.g., survival of Kirtland's warblers), but must be relevant to the ecosystem they represent and susceptible to the stressors of concern (EPA, 1998; Suter et al., 1993).

Section 7(a)(2) of The Endangered Species Act, Counterpart Regulations and various lawsuit settlements and implementing regulations consistently indicate that the protection goal for listed species potentially exposed to pesticides is no jeopardy to their continued existence and/or destruction or adverse modification of their habitat. Therefore, the protection goal for the Kirtland's warbler is to ensure that exposure to malathion is not likely to adversely affect the continued existence of the species, result in the destruction or adverse modification of the habitat of the Kirtland's warbler (e.g., jack pine forests), or significantly reduce the prey upon which the Kirtland's warbler depends.

For direct effects to the Kirtland's warbler, the assessment endpoint is the survival, reproduction and growth of individuals of this species. These endpoints are directly relevant to protection at the population level of organization.

For indirect effects to the Kirtland's warbler, the assessment endpoint is the productivity of prey communities. The prey availability assessment endpoint is at the community level of organization because the Kirtland's warbler is a generalist feeder and modification of the availability of only a few sensitive individuals is unlikely to impact the overall availability of terrestrial invertebrate prey. The habitat assessment endpoint is not considered further because malathion is not a concern for terrestrial plants in Kirtland's warbler habitats.

2.7 Conceptual Model

For Kirtland's warblers during the breeding season, the stressor is the release of malathion into the environment via spray drift following application. For migrating Kirtland's warblers, the stressor is malathion applied to orchards that could be stopover locations. The receptors of concern are Kirtland's warblers and the terrestrial invertebrates they prey upon. The pathway of concern for exposure of Kirtland's warbler is ingestion of contaminated dietary items.

2.8 Analysis Plan

In our assessment, both direct and indirect effects to the Kirtland's warbler during the breeding season and during migration were evaluated. The refined risk assessment for malathion was conducted in three phases: exposure assessment, effects assessment and risk characterization.

2.8.1 Exposure Assessment

Probabilistic, species-specific exposure models were developed to assess risks of MAL to Kirtland's warblers during the breeding season and during spring and fall migration. The breeding area model simulates acute and chronic exposure to each of 10,000 birds over a 60-day period following initial MAL application. The model time step is ten minutes, which is the approximate interval for foraging trips from the nest. At each time step for each bird, the model randomly determines distance between foraging location and the closest edge of the closest treated area. The Tier 1 AgDRIFT model is then used to determine fraction of applied MAL reaching the foraging location, which is multiplied by estimated treated area dietary concentrations to determine dietary concentrations at the foraging location. The standard passerine allometric model is used to determine dietary intake of MAL at each time step. This process is repeated at each time step. Acute exposure is determined by combining dietary intake with the rate of elimination for birds to determine body burden at each time step. Peak body burden over the 60-day model run is the acute exposure metric ultimately used to determine the fate of each simulated bird. For chronic exposure, 21-day rolling average total daily intake (TDI) is determined for each day in the model beginning at day 21. The 21-day duration was selected to approximately match the exposure duration associated with chronic reproductive effects to the most sensitive species tested. The peak 21-day rolling average TDI is the chronic exposure metric ultimately used to determine if the bird could experience adverse effects on reproduction. For terrestrial invertebrates, the exposure metric is the peak concentration on terrestrial invertebrates that occurred in Kirtland's warbler foraging locations during the model simulation. For the breeding area assessment, we simulated a representative use pattern for each of the seven crop classes that could be within 3 km of the breeding areas of Kirtland's warbler (e.g., corn, vegetables and ground fruits, pasture/hay, etc.). In all cases, we assumed the maximum application rate and number of applications, and the minimum treatment interval.

The migration model simulates 10,000 birds during the course of their 12- to 23-day migration between their breeding area and the Bahamas. The model has an hourly time step and can be used to simulate spring or fall migration. Typically, Kirtland's warblers have only one to three stopovers during migration during which they actively forage for an extended duration (typically one day but can be up to six days). In the model, two stopovers are assumed which occur on randomly chosen days during the first half and during the second half of the migration period, itself a randomly determined duration. The duration of each stopover is randomly determined. The vast majority of stopovers will be in habitats that cannot be treated with malathion (mostly scrub-shrub vegetation). However, on occasion warblers may stopover in orchards that could be treated with MAL (e.g., apples in the Northeast, peaches in Georgia, oranges in Florida). Thus, during each stopover, the model randomly determines whether the simulated bird is in an orchard, whether that orchard has been treated with MAL, and, if treated, the time since the last application occurred. This information is used to determine dietary concentrations to which each bird is exposed during the stopover. The acute exposure metric (i.e., peak body burden) is determined using the same approach as in the breeding area model. Chronic exposure is not estimated in the migration model because of the limited number of short stopovers that occur during migration. In the migration model, we simulated multiple use patterns at the same time because each bird could encounter different types of orchards during a migration.

2.8.2 Effects Assessment

Species-specific toxicity data were not available for the Kirtland's warbler. For acute exposures, insufficient data were available to develop an SSD or dose-response curve. Therefore, the lowest LC50 from an acceptable acute oral avian toxicity study was used. The selection of this threshold further increases the conservativism of this assessment because data from acceptable studies suggest that passerines are not the most sensitive species to malathion (Stafford, 2011 [MRID 48571805]; Hubbard and Beavers, 2012c [MRID 48963305]).

For chronic exposures, insufficient data were available to develop an SSD or dose-response curve. Therefore, the lowest NOEL from an acceptable reproduction study was used.

Chronic exposures were only evaluated for birds on the breeding habitat. During migration, stopovers for foraging only last on average 1.23 days (Petrucha et al., 2013). Therefore, chronic exposures would not occur. Wintering habitat is not located in the United States, and thus is not considered in this assessment.

To evaluate the potential for indirect effects to the Kirtland's warbler of a reduction in prey availability, the LC10 for the most sensitive test species was compared to predicted concentrations. This endpoint was chosen to increase the conservatism in this assessment. Similar to birds, invertebrate toxicity data were evaluated for quality and only acceptable studies were considered.

2.8.3 Risk Characterization

To estimate acute risk, percent survival was estimated for the Kirtland's warbler for each malathion use pattern relevant to the breeding areas of Kirtland's warbler and for the combination of use patterns that could be encountered by Kirtland's warblers during migration. For chronic risk, we calculated the percentage of Kirtland's warblers that would have chronic doses exceeding the most sensitive NOEL during the breeding season. As noted previously, chronic exposure to malathion would not occur during spring or fall migration.

To estimate potential risks to terrestrial invertebrates, the probability of exposure exceeding the most sensitive LC10 was estimated for each malathion use pattern relevant to the breeding areas of Kirtland's warbler.

3.0 EXPOSURE ASSESSMENT – BREEDING AREA MODEL

For the Kirtland warbler's assessment, separate models were developed to determine risks during the breeding season and during spring and fall migration. These models and their associated input parameters are described in this chapter (breeding area model) and chapter 4 (migration model). Following the descriptions of the model and input parameters, we present the exposure results and the results of detailed sensitivity analyses.

The breeding area model estimates both acute and chronic risk for Kirtland's warbler potentially exposed to malathion. To estimate acute risk, the model determines the peak body burden for each bird that occurred during the breeding season and compares that value to a randomly chosen value from the most sensitive oral gavage dose-response curve. If the peak body burden exceeds the effects value, the bird dies. Otherwise, the bird survives. For chronic exposure, the peak rolling average total daily intake that occurred during the growing season for each bird is determined and compared to most sensitive available NOEL. The duration of the rolling average is a conservative estimate of the exposure period that led to the observed effects in the chronic toxicity study used to derive the effects metrics. The breeding area model is probabilistic and was used to simulate risk to 10,000 birds for each exposure scenario.

The first step in the model is to define the exposure scenario (i.e., crop, number of applications, treatment interval, application rate and method, droplet spectra). This information is used to estimate the initial (t_0) concentrations of malathion in dietary items (i.e., foliage-dwelling invertebrates, small fruits) on treated fields. Degradation rates are then used to determine the concentrations of malathion on dietary items at each time step following initial application. The time step for the breeding area model is defined by the user. A default time step of 10 minutes was selected to roughly approximate the foraging frequency of male Kirtland's warblers during nesting and female Kirtland's warblers once they resume foraging after the early nestling period (males often feed females during brooding) (Walkinshaw, 1983). If there is more than one pesticide application, the model estimates concentrations for each application on the application dates specified by the user. For second, third and fourth applications, where applicable, residue concentrations existing prior to the application are added to the residue concentrations estimated for the new application. With a ten-minute time step, the model duration is 60 days.

Because Kirtland's warblers forage exclusively within their territories located in young jack pine forests during the breeding season (Probst, 1988; Probst and Weinrich, 1993; Fussman, 1997; FWS, 1985, 2012), they would not be exposed to malathion in dietary items located in treated areas. Thus, dietary concentrations must be adjusted to account for the distance between where warblers forage and treated areas. EPA's Tier 1 AgDRIFT, version 2.1.1 spray drift model (https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/models-pesticide-risk-assessment) was used to estimate downwind deposition of spray drift from aerial, ground boom and orchard/vineyard airblast applications. We conservatively assumed that spray drift is always in the direction of the Kirtland's warbler territory in the breeding area model.

In each time step, the breeding area model randomly determines the foraging location of the Kirtland's warbler in its territory and then determines the distance between that foraging location and the closest edge of the treated area. With that information, and knowledge of the crop type, application method and spray droplet spectra, AgDRIFT can be used to calculate the fraction of the application rate that reached the foraging location. The model then simply multiplies that spray drift fraction by the treated area concentration for each dietary item to determine dietary concentrations at the foraging location. The distance in meters between foraging location and the closest edge of the treated area (D_T) requires summing the distance from the foraging location to the territory edge closest to the treated area (D_{NA}), and the distance from that territory edge to the closest edge of the treated area (D_{TA}).

$$D_T = D_{NA} + D_{TA} \quad \textbf{Equation 3-1}$$

where,

D_T is the total distance from bird foraging location to the closest edge of the treated area;
D_{NA} is the distance from bird foraging location in the nesting area to territory edge; and
D_{TA} is the distance from the territory edge to the closest edge of the treated area.

An example showing foraging distance of versus time output for randomly chosen Kirtland's warbler is shown in Figure 3-1.

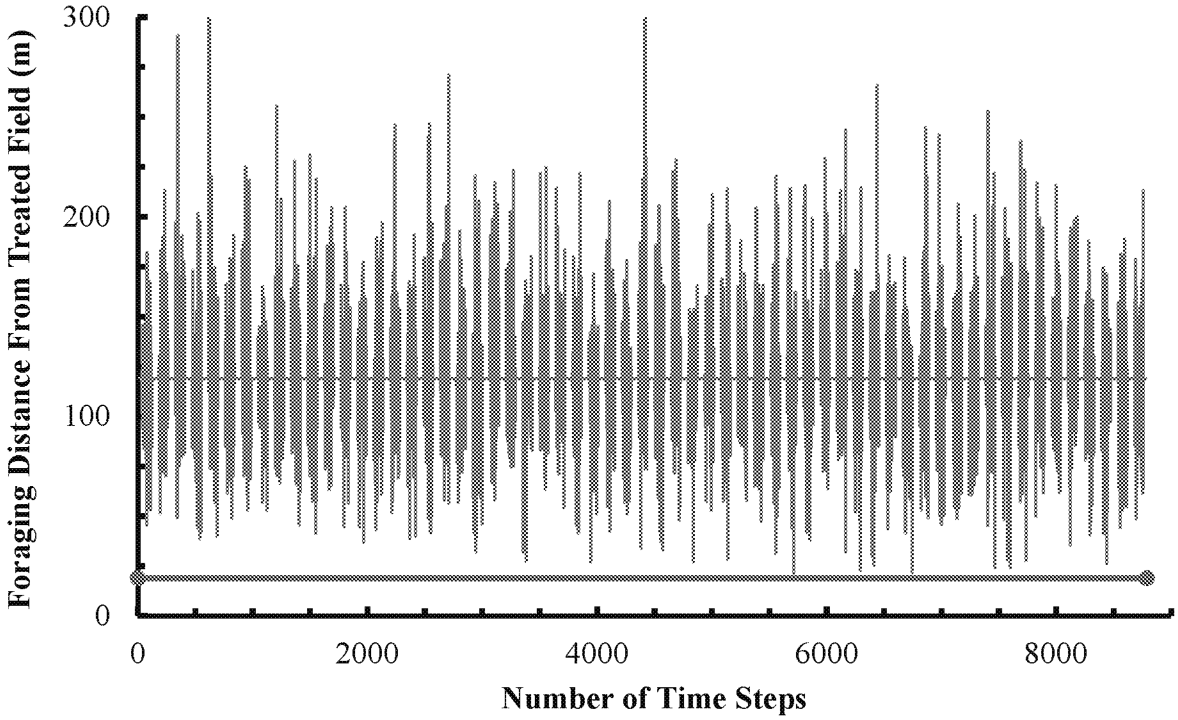

Figure 3-1 Bird location over time relative to the closest edge of the treated area (blue). The time step is ten minutes. The edge of the bird territory is indicated in orange and is 22 m from the closest edge of the treated area. The nest location is indicated by the straight horizontal blue line and is 120 m from the closest edge of the treated area.

To calculate dose at each time step, food intake rate is multiplied by dietary concentration and the proportion of the dietary item for each item in the diet. Food intake rate is based on an allometric relationship for passerine birds (Nagy et al., 1999). Each individual body mass used as an input to the allometric relationship is randomly sampled from body weight distributions specific to males, females, or combined sexes (i.e., assuming 1:1 ratios of males to females) of the Kirtland's warbler. In this assessment, we assumed a 1:1 ratio of males to females. Thus, the dose for an individual bird for a given time step is:

$$D_{TS} = PDI \times FIR \times \sum_{i=1}^{2} C_i \, x \, P_i \qquad \textbf{Equation 3-2}$$

where,

- D_{TS} is the time step (TS = 10 minutes) dose (mg ai/kg bw/time step),
- PDI is proportion of the total daily food and water intake occurring in that time step;
- FIR is food intake rate (kg ww/kg bw/d);
- C_i is concentration in the i^{th} dietary item (mg ai/kg bw); and
- P_i is proportion of the i^{th} dietary item in the diet.

The amount of malathion retained by a bird (i.e., body burden) from one time step to the next is governed by the rate of metabolism:

$$RD_t = D_{TS} + RD_{t-1} \; x \; f_{retained} \qquad \textbf{Equation 3-3}$$

where,

RD is retained dose (mg ai/kg bw);
D_{TS} is the dose from the current time step (mg ai/kg bw/time step);
t is the current time step;
t-1 is the previous time step; and
$f_{retained}$ is the fraction of malathion retained in the bird after accounting for metabolism and elimination of the compound.

Once *RD* has been calculated for each of the time steps in the breeding area model (60 d x 24 hr/d x 6 time steps/hr = 8640 hourly time steps), the model searches for the peak hourly retained dose (i.e., body burden) to determine acute exposure, and the peak rolling-average *TDI* (total daily intake) for chronic exposure that occurred following initial malathion application. It is these peak exposure values that are compared to the acute and chronic effects metrics to determine if the bird is adversely affected (Figure 3-2).

The approach used in the breeding area model to determine the fate of an individual bird for an acute exposure is the same as that used by EPA (2005) and Moore et al. (2014a). The first step is to estimate the *Z* score of the maximum hourly retained dose. The *Z* score is calculated as:

$$Z = (\log RD_{max} - \log LD50) \; x \; Slope \qquad \textbf{Equation 3-4}$$

where,

RD_{max} is the maximum retained dose (mg ai/kg bw);
LD50 is the dose estimated to cause 50% mortality; and
Slope is the probit slope of the dose-response curve.

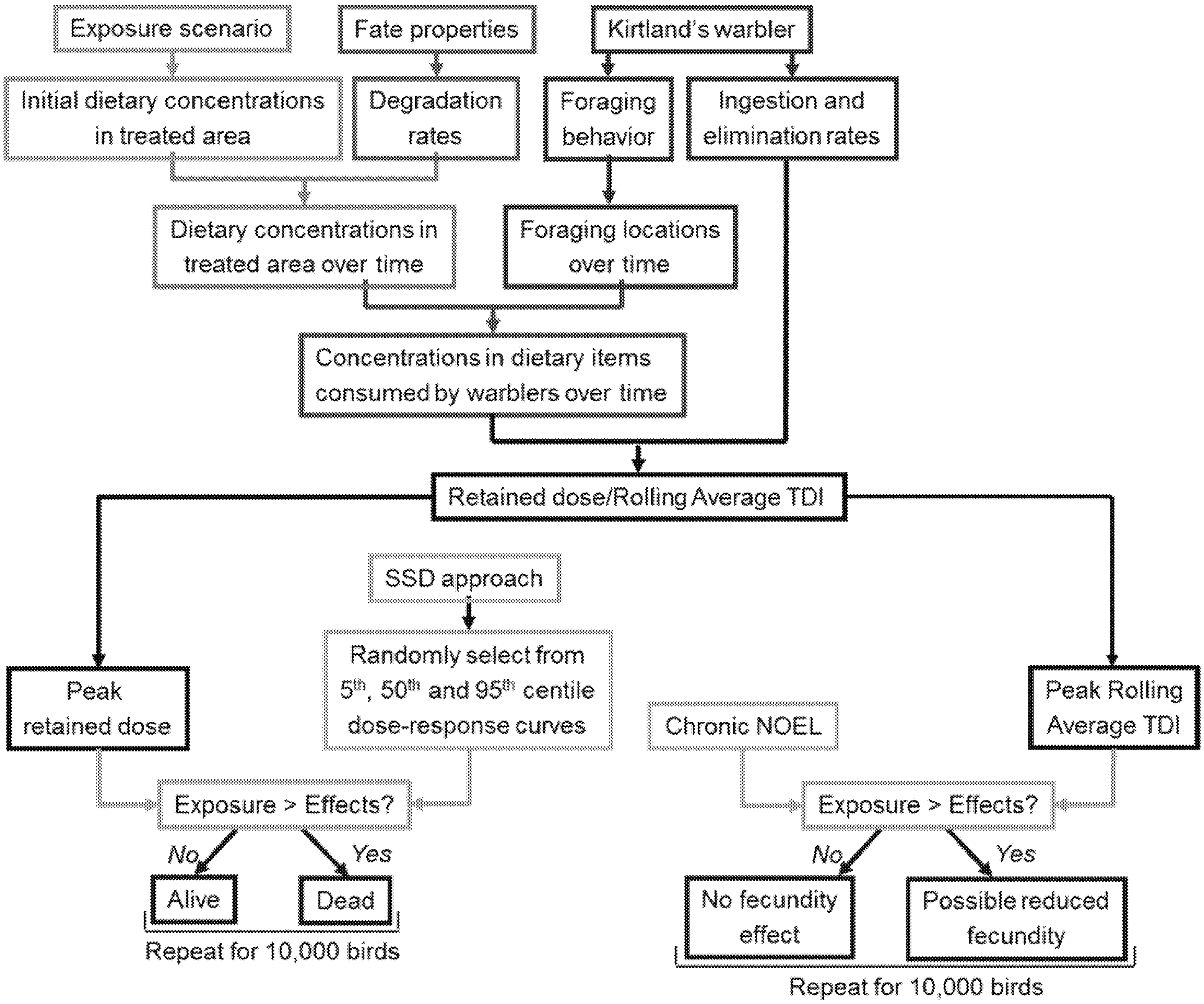

Figure 3-2 Components of the breeding area model for the Kirtland's warbler

The *Z* score is an estimate of where the maximum retained dose would occur on the acute dose-response curve derived using a log-probit model. Next, the *Z* score is converted to a value with a range from zero to one by entering the *Z* score in the standard normal distribution (mean = 0, standard deviation = 1). The resulting value is the individual risk estimate. The determination of whether a bird survives or dies is made by comparing the individual risk estimate to a randomly selected value from a uniform distribution with a range of zero to one. If the random number is less than the individual risk estimate, the individual is dead. Otherwise, the bird survives. This process is repeated for each of the 10,000 birds included in a simulation.

Ideally, a similar methodology would be used to determine chronic effects with the goal of determining magnitude of effect to each bird rather than the acute binary effect of alive or dead. However, in the case of malathion, no chronic studies were available for birds with a sufficient number of treatments to enable derivation of a dose-response curve. For this assessment, we estimated the probabilities that the maximum chronic *TDI* exceeded the NOEL and the LOEL for the most sensitive species tested.

Section 3.1 describes the equations and inputs used in the exposure modeling conducted for Kirtland's warbler exposed to malathion in their breeding area.

3.1 Input Parameters for Exposure Component of Breeding Area Model

3.1.1 Crop

To account for possible crop rotation and changes to cropping patterns over time, EPA (2016) grouped all agricultural use patterns into 11 general classes: corn, cotton, rice, soybeans, wheat, vegetables and ground fruits, orchards and vineyards, other grains (e.g., rye, oats), other row crops (e.g., sunflower, peanuts), other crops (e.g., sod, grass seed, wildflowers), and pasture/hay (e.g., alfalfa, hay). For the breeding area model, we selected a representative use pattern from the malathion labels (i.e., see Appendix A) for each general class, except for the cotton, rice, soybean, and wheat general classes because they do not occur in close enough proximity for spray drift to reach Kirtland's warbler breeding areas. Each of the remaining representative use patterns could lead to exposure of Kirtland's warblers. The representative use patterns could occur in reasonable proximity to Kirtland's warbler breeding areas and generally had application rates similar to or higher than other use patterns in the crop class. The modeled use patterns are shown in Table 3-1. In each case, we assumed the maximum application rate and number of applications and minimum interval between applications as per the labels (Appendix A). We also ran simulations for both ground and aerial applications, where permitted on one or more labels (see Appendix A), assuming a medium to coarse droplet size spectrum, as specified on the labels. A buffer of 0 feet was assumed for ground and airblast applications, whereas a buffer of 25 feet was assumed for aerial applications, as per label instructions.

Table 3-1 Use patterns modeled for Kirtland's warbler during the breeding season

Crop Class	*Representative Use Pattern*	*Application Rate (lb ai/A)*	*No. of Applications*	*Interval (d)*	*Application Method*
Corn	Corn	1	2	7	Aerial, Ground
Vegetables and Ground Fruits	Potato	1.56	2	7	Aerial, Ground
Orchards and Vineyards	Apple	1.25	2	7	Aerial, Ground, Airblast
Other Grains	Oats	1	2	7	Aerial, Ground
Other Row Crops	Dry bean	.61	2	7	Aerial, Ground
Other Crops	Christmas tree	3.2	2	7	Aerial, Ground
Pasture/Hay	Alfalfa	1.25	2[a]	14	Aerial, Ground

[a]Number of applications per cutting.

3.1.2 Nomograms for Invertebrates and Blueberries

Because concentrations of malathion on terrestrial invertebrates and blueberries in treated areas shortly after application are not available for most use patterns, a nomogram is generally used to estimate predicted concentrations of pesticide residues on dietary items consumed by wildlife. The EPA uses nomograms based on applications to terrestrial crops to estimate exposure to non-target species (Baehr and Habig, 2001). The terrestrial nomograms were described by Hoerger and Kenaga (1972) and Kenaga (1973) and subsequently re-evaluated by Fletcher et al. (1994). The nomograms produced by Fletcher et al. (1994) estimate residues on short grass, long grass, leafy crops and forage, fruits, and seeds. Residues from a unit dosage (RUDs) are calculated by dividing the measured concentrations from a variety of field studies by corresponding application rates. Concentrations of pesticide present on each dietary item are assumed to be directly proportional to rate of application. This method of normalization assumes that method and timing of application are unimportant, and run-off from the plant is insignificant (Baehr and Habig, 2001).

Numerous field studies have been conducted to determine concentrations of malathion on dietary items following application. These studies were reviewed with the goal of deriving malathion-specific RUDs for dietary items of Kirtland's warbler feeding in orchards, as this is the closest approximation to the young jack pine forests where they normally forage. Because Kirtland's warblers primarily forage on foliage-dwelling invertebrates, we derived an RUD specific to this group of invertebrates. By using data for the day of application for small fruits and peak values for invertebrates from day of application or the following day, means and standard deviations for each dietary item were calculated.

Because distributions for each RUD were intended to represent among-application variability, only one set of values per application were used in the calculations. The final RUDs used in the breeding area model are shown in Table 3-2. In the breeding area model, the calculated means and standard deviations from field studies were used to parameterize lognormal distributions. In the modeling runs, random values were drawn from the RUD distributions for each simulated bird. The randomly chosen values were then multiplied by the corresponding application rate to estimate starting residue concentrations on each dietary item in the treated area.

Table 3-2 Day 0 residue values (RUDs) on areas treated with malathion

Crop Type	*Dietary Item*	*RUD (mg ai/kg ww/lb ai/A)*			*References*
		Mean	*Standard Deviation*	*Sample Size*	
Orchards	Foliage-dwelling invertebrates	15.67	28.58	15	Barber et al., 2005 [47841001]; Brewer et al., 2003; Forsyth and Westcott, 1994; Hanebeck and Staedtler, 2011 [49086411]; Powell, 1984; Staedtler et al., 2011 [49086410]; Stromborg et al., 1982; Stromborg et al., 1984
	Fruits	0.916	1.145	58	Moore et al., 2014b [49389301]

3.1.3 Dissipation Rates

Residue measurements on terrestrial arthropods post malathion application were available from three studies (Knäbe, 2004 [MRID 46525902]; Hanebeck and Staedtler, 2011 [MRID 49086411] and Staedtler et al., 2011 [MRID 49086410]). In general, malathion was applied to the field, and terrestrial arthropods were collected at various times post application via pitfall traps, and/or inventory spraying. Residues were subsequently measured on ground- and crop-dwelling arthropods. Data used to estimate trial specific DT50s are presented in Appendix B. Due to the paucity of data for individual arthropod types, residues were pooled to determine a common DT50 for terrestrial arthropods.

For samples with residue concentrations below the limit of detection (ND), concentrations were set to ½ of the limit of detection (LOD) and all subsequent samples (per time point) were omitted from the DT50 analysis. For samples with residue concentrations between the LOD and the limit of quantification (LOQ), concentrations were set to the average of the LOD and LOQ. For each trial, the measured residue data were then natural log transformed. Linear regression modeling was conducted to determine intercepts and slopes using Microsoft® Excel 2007. This approach assumes first-order degradation kinetics. DT50s were subsequently calculated using Equation 3-5.

$$DT50 = \frac{Ln(0.5)}{Slope}$$ **Equation 3-5**

DT50 estimates were averaged per trial, and then a 90% upper confidence limit on the mean was calculated assuming a t-distribution. A summary of estimated DT50s and T90s are presented in Table 3-3, below. The terrestrial arthropod mean DT50 and T90 for malathion was estimated to be 2.31 and 3.54 days, respectively.

Table 3-3 Summary of terrestrial arthropod DT50s for malathion

Study	*Application*	*Medium*	*DT50 (d)*	*Average DT50 per Study (d)*	*LN(DT50)*
Knäbe, 2004a [MRID 46525902]	1	Ground-dwellers	2.30	3.49	1.25
	1	Foliage-dwellers	4.68		
Hanebeck and Staedtler, 2011 [MRID 49086411]	1	Ground-dwellers	1.36	1.23	0.206
	1	Foliage-dwellers	1.09		
Staedtler et al. 2011 [MRID 49086410]	1	Ground-dwellers	1.21	2.20	0.786
	1	Foliage-dwellers	0.968		
	2	Ground-dwellers	3.28		
	2	Foliage-dwellers	3.32		
			Overall Average (d)	2.31	

As with terrestrial invertebrates, there were a number of field studies available to calculate a dissipation half-life for malathion on small fruits. Moore et al. (2014b [MRID 49389301]) presented between 50 and 60 estimated dissipation half-life (DT50s) values for malathion for each of foliage, small fruit and large fruit feed item categories. For small fruit, a dissipation half-life of 5.06 days was calculated.

The dissipation rates for Kirtland's warbler dietary items calculated from the mean half-life values were 0.137 and 0.300 d^{-1} for small fruits and foliage-dwelling invertebrates, respectively.

To calculate concentrations in dietary items on treated areas in the time steps following application of malathion, the breeding area model dissipates the time zero concentration in each treated area according to the equation:

$$C_k(t) = C_k(t_0)e^{-rt}$$ **Equation 3-6**

where,

> $C_k(t)$ is the residue concentration in the k^{th} dietary item at time step t after treatment (mg/kg ww);
> $C_k(t_0)$ is the randomly selected starting residue concentration at time zero in the treated area of interest;
> r is the dissipation rate constant for MAL in the k^{th} dietary item; and
> t is the time in ten minute increments after MAL application.

3.1.4 Proximity of Crop Class to Kirtland's Warbler Breeding Areas

The species range information for the Kirtland's warbler and malathion crop footprint were determined for malathion (Figure 3-3).

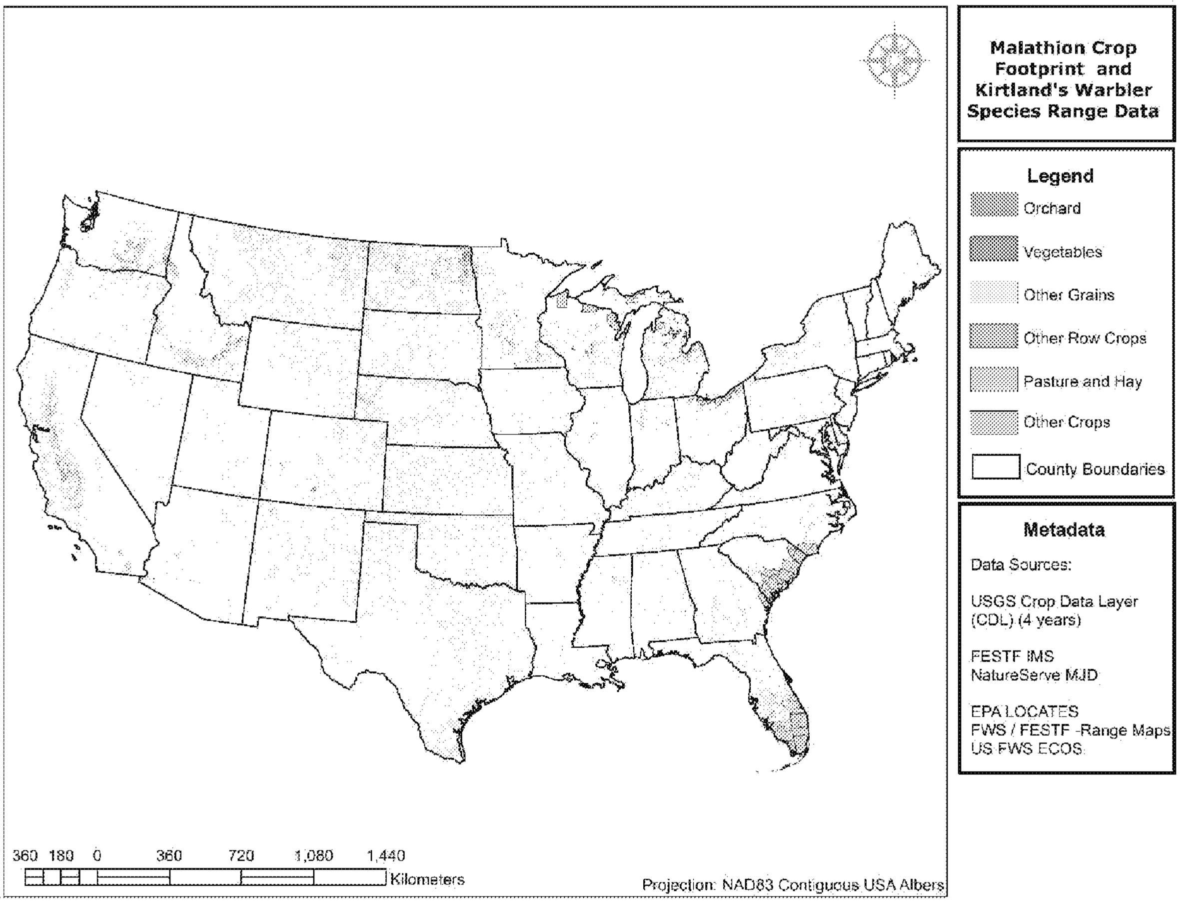

Figure 3-3 Malathion crop footprint and Kirtland's warbler species range

Crop footprints were developed for malathion to determine the extent of uses based on the malathion labels, excluding mosquitocides. The primary source of this information was the master list of malathion uses registered by Cheminova.

Crop footprints represent the spatial extent of agricultural use sites for a given pesticide. Crop footprints are based on the most recent years of Cropland Data Layer (CDL) data available, starting with 2010. A national CDL layer is available for 2009; however, it was based on lower resolution imagery (56-m) before being resampled to the now standard 30-m resolution. Labeled uses were cross-walked to the appropriate crop(s) in the CDL and then grouped based on the crop classes defined by EPA. Any geographic use directions or restrictions (such as “Not labeled for use in MS”) were considered and the corresponding crop(s) in that area removed from the footprint. Presence in any of the CDL layers for a given labeled crop resulted in presence for that crop in the crop group footprint. This approach differs from that outlined by EPA in that it does not include expansion, or “region growing” into adjacent cultivated land to adjust to USDA Census of Agriculture levels and crops not labeled for use as well as geographic restrictions were removed from the appropriate footprint.

For malathion, FESTF developed formulation-specific crop footprints. These footprints represent the uses supported by Cheminova for each formulation and take into consideration geographic use restrictions.

The calculation of proximity distances from Kirtland's warbler locations was conducted independently for each crop class. The distances were calculated using vector-based geoprocessing methods that required each crop group footprint to be converted from a raster dataset to a vector dataset. The ArcGIS (version 10.2.2) "Near" tool was used to determine the closest distance from the edge of every Kirtland's warbler location (element occurrence (EO), or critical habitat polygon or linear feature) to the crop group footprint. An example of this calculation is shown in Figure 3-4. The "Near" tool was executed from within a Python script that was written to loop through every species EO and habitat area, calculate the proximity, and write the results to an Access database. This approach was found to be computationally more efficient than executing the "Near" using the entire EO or critical habitat dataset as an input. A limit of 3048 meters (≈ 3 km) was placed on how far away an EO could be from a crop footprint to calculate an exact distance. Any case where a crop footprint was greater than 3048 meters from an EO, the distance was recorded in the proximity database as 3048 m.

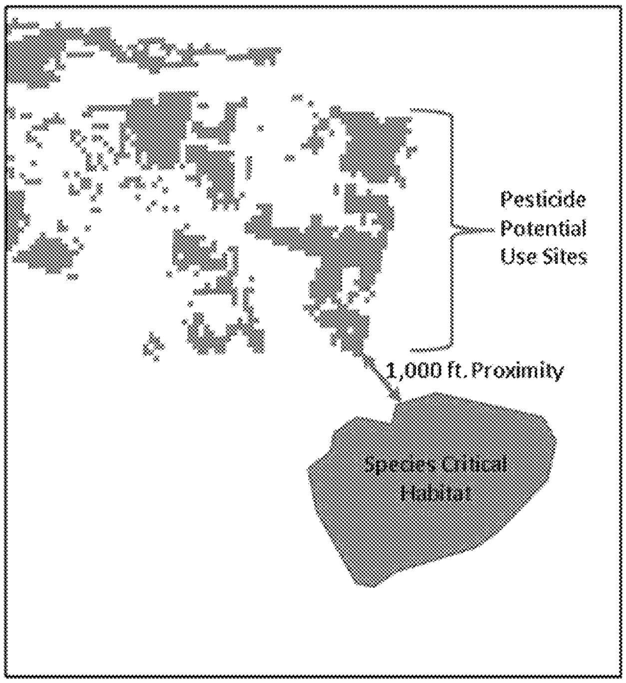

Figure 3-4 Schematic of proximity of pesticide use site to species habitat

Following the proximity calculations, the county identifier (Federal Information Processing Standard (FIPS) Code) was assigned to all species habitats. In some cases, a FIPS was already assigned in the original database to a species habitat, such as for MJD habitats or county-level habitat features. If a species feature did not have a FIPS code assigned in the original database, the species habitat was combined (union operation) with county boundaries (GeoStac; CLA, 2015) using the ArcGIS (Version 10.2.2.) "Union" tool. This enabled the FIPS information to be associated with species features. Where species features crossed county boundaries, the species features were split by the "Union" tool and associated with each of the county FIPS codes. The results were placed in an Access database to facilitate data organization and flexibility of use.

The proximity database was then queried to locate the sub-county range data for the Kirtland's warbler in the Michigan and Wisconsin breeding areas for the breeding area analysis. A total of 55 records (identified as sub-county records from the NatureServe MJD licensed dataset) were found. Each record contained the proximity distance from the Kirtland's warbler locational data to the closest polygon or point representing a crop group. These data were combined in the Kirtland's warbler breeding area model as empirical distributions for each crop class. For each bird simulated for a particular use pattern, a random proximity distance was sampled from the empirical distribution for the corresponding crop class.

3.1.5 Territory Size and Nest Location

Walkinshaw (1983) observed that Kirtland's warbler breeding area territories range from 4.12 to 8.48 ha in favorable habitats (mean = 6.3 ha). Assuming circular territories, which is typical for natural habitats though territory shape may be more rectangular in managed jack pine forests (Walkinshaw, 1983), territory diameter varies from 229 to 329 m (mean = 283 m). In the breeding area model, territory diameter is randomly sampled from a betapert distribution for each simulated bird using the mean, minimum and maximum diameters of 283, 229 and 329 m.

Mayfield (1960) observed that nests are typically located in the central portion of the territory, with a minimum distance of at least 18.9 m from the nearest territory edge (which is approximately 0.07 of mean territory diameter) (also see Bocetti, 1994). In the breeding area model, we need only estimate foraging location relative to the closest edge of the treated field to determine fraction of spray drift reaching that location. Thus, movement parallel to the treated area can be ignored, assuming that spray drift is blowing directly at the territory. To determine nest location in the model, a betapert distribution with a median of 0.5, minimum of 0.07 and maximum of 0.93 (the latter values ensure nest locations are >18.9 m from nearest territory edge) is randomly sampled for each simulated bird. The randomly chosen value is then multiplied by the randomly chosen territory diameter to determine distance of the nest from the territory edge closest to the treated field.

3.1.6 Foraging Distance from the Nest

Mayfield (1960) observed that Kirtland's warblers rarely forage more than 100 m from the nest and most food is gathered within 10 m because food is abundant during the breeding season. In the breeding area model, we assumed an exponential distribution with a rate of 0.05 that ensures most foraging occurs within 10 m of the nest and rarely exceeds 100 m from the nest. This distribution is sampled at each time step to determine distance from the nest perpendicular to the closest edge of the treated field (Figure 3-1). The model, however, constrains foraging distance from the nest such that the bird cannot leave its territory. This distance plus the distance of the nest from the territory edge closest to the treated area produces the D_{NA} value in Equation 3-1.

3.1.7 Fraction of Application Reaching Kirtland Warbler's Foraging Locations

The breeding area model calculates the distance from the closest edge of the treated area to the warbler foraging location at each time step in the model (Figure 3-1). This information is then input to Tier 1 AgDRIFT, version 2.1.1 to determine the fraction of the malathion application reaching each foraging location. The equation to determine spray drift fraction is:

$$Deposition\ fraction = \frac{c}{(1+ax)^b} \qquad \textbf{Equation 3-7}$$

where x is distance in meters. An analysis of the deposition curves generated from AgDRIFT 2.1.1 yielded the parameters shown in Table 3-4 for different application methods and droplet spectra (EPA, 2016). For some application methods, the curves were split at a particular distance to obtain a better fit to the data. The break point distances were determined by visual observation.

Table 3-4 Parameters for spray drift equations (from EPA, 2016)

Application Method	*Droplet Spectrum (distance from edge of field)*	*a*	*b*	*c*
Aerial	Very Fine to Fine (< 43 m)	0.0204	0.7278	0.5001
	Very Fine to Fine (≥ 43 m)	0.0292	0.8220	0.6539
	Fine To Medium (< 16 m)	0.1187	0.5699	0.5000
	Fine To Medium (≥ 16 m)	0.0241	0.8689	0.1678
	Medium to Coarse	0.0721	1.0977	0.4999
	Coarse to Very Coarse	0.1014	1.1344	0.4999
Ground[a], high boom	Very Fine to Fine	0.1913	1.2366	1.0552
	Fine to Medium/Coarse	2.4154	0.9077	1.0128
Ground[a], low boom	Very Fine to Fine	1.0063	0.9998	1.0193
	Fine to Medium Coarse	5.5513	0.8523	1.0079
Airblast, vineyard	Not applicable	0.1349	1.4405	0.0376
Airblast, orchard	Not applicable (<26 m)	0.0414	2.1054	0.2223
	Not applicable (≥ 26 m)	6.7728	1.2788	27.027

[a] Equations generate 90th percentile deposition values.

To determine dietary concentrations at each foraging location, treated field concentrations are simply multiplied by the deposition fraction given the distance from the closest edge of the treated field to the foraging location. This calculation is repeated for each time step.

3.1.8 Body Weight

Individual body weights were used to calculate daily rates of ingestion of food for each simulated Kirtland's warbler. There is a slight difference between weights of male and female Kirtland's warblers. The breeding area model contains body weight distributions for males and females.

In the breeding area model, the sex of each simulated bird was randomly determined by sampling from a discrete uniform distribution with a minimum of one (i.e., males) and a maximum of two (i.e., females). Once the sex of the bird was determined, a body weight was randomly drawn from a normal distribution for that sex based on empirical data collected for the Kirtland's warbler. Goodman (1982) determined the following body weight parameters for adult Kirtland's warblers: males (n = 31): mean = 13.6 g, standard deviation = 0.59; and females (n = 11): mean = 14.3 g, standard deviation = 1.18. These parameters were used in the breeding area model. Mayfield (1960) and Walkinshaw (1983) observed similar body weight measurements. Bocetti (1994) found that nestlings are close to adult body weights at 10 days after hatching (mean = 13.1 g).

3.1.9 Food Ingestion Rate

Free-living birds, unlike captive birds, expend energy foraging for prey, avoiding predators, defending territories, etc. As done by EPA (2005), an allometric modeling approach based on free-living birds was used to estimate food intake rate for Kirtland's warblers. Food intake rate was derived as follows:

$$FIR = \frac{FMR}{\sum_{i=1}^{n} AE_i \cdot GE_i} \qquad \textbf{Equation 3-8}$$

where,

FMR is normalized free metabolic rate (kcal/kg bw/d);
AE_i is assimilation efficiency of i^{th} dietary item (unitless); and
GE_i is gross energy of i^{th} dietary item (kcal/kg ww).

The model used the allometric relationship of Nagy et al. (1999) developed for passerines to estimate free metabolic rate for Kirtland's warbler. The FMR equation has the general form:

$$FMR\left(\frac{kJ}{d}\right) = a \cdot BW(g)^b \qquad \textbf{Equation 3-9}$$

In the breeding area model, *FMR* was estimated probabilistically by incorporating the distributions for body weight (*BW*), rather than a point estimate, and by incorporating uncertainty resulting from lack of model fit (*LMF*) in the fitted allometric relationship (i.e., a normal distribution parameterized with a mean of zero and a standard deviation calculated as the square root of the unexplained sum of squares from the fitted allometric regression model). The slope (*a*) and power (*b*) parameters and unexplained sum of squares were based on regression analyses of the data reported in Nagy et al. (1999), assuming an underlying normal distribution (*N*) for the latter. The resulting equation for *FMR* for passerines was calculated as:

$$FMR\left(\frac{kJ}{d}\right) = 10^{1.00225}\, x\, BW(g)^{0.69279}\, x\, (LMF = 10^{N(0,0.11212)})$$ **Equation 3-10**

where,

N is a normal distribution with parameters mean and standard deviation in brackets.

3.1.10 Assimilation Efficiency and Gross Energy

To calculate rate of ingestion of food (*FIR*) for each bird, gross energy (*GE*) and assimilation efficiency (*AE*) are required for each dietary item. Combined, these two parameters yield the metabolizable energy (*ME* = *GE* x *AE*) of the dietary item. Gross energy represents the total amount of energy available from a dietary item. Assimilation efficiency represents the proportion of available energy that an organism can obtain from a particular dietary item. Assimilation efficiencies of different dietary items were assigned beta distributions in the breeding area model. The parameters used to generate the distributions are shown in Table 3-5 and were based upon the measures of centrality and spread reported in the literature (see EPA, 1993 for a summary). As was done by EPA (2005), distributions of efficiencies of assimilation were scaled to avoid implausibly small or large values:

$$AE_{scaled} = AE_{minimum} + AE_{mean}\, x\, AE_{range}$$ **Equation 3-11**

Gross energy values for dietary items were also obtained from the Wildlife Exposure Factors Handbook (EPA, 1993) (Table 3-6). In the breeding area model for Kirtland's warbler, a lognormal distribution was assumed for gross energy of each dietary item, as was assumed by EPA (2005). Distributions were truncated at the 0.01th and 99.99th centiles to avoid implausibly small and large values, respectively.

Table 3-5 Assimilation efficiencies for birds consuming dietary items

Dietary Item	Statistical Parameter							Scaled Assimilation Efficiency
	Mean	SD	Alpha	Beta	Minimum	Maximum	Range	
Invertebrates	0.72	0.051	55.1	21.4	0.513	0.880	0.367	0.777
Fruits	0.64	0.150	5.91	3.33	0.118	0.982	0.865	0.671

Table 3-6 Gross energies of dietary items (kcal/kg ww)

Item	Statistical Parameter			
	Mean	SD	Minimum	Maximum
Invertebrates	1600	260	866	2879
Fruits	1100	300	391	2873

3.1.11 Rate of Metabolism and Elimination of Malathion by Birds

A GLP study following the Pesticide Assessment Guidelines, Subdivision O, Section 171-4(b) conducted by Cannon et al. (1993 [MRID 42715401]) investigated the metabolism and excretion of [2,3-^{14}C]-malathion in white leghorn chickens. Four control and four treated birds were used in the study. Treated birds received 3.8 mg of malathion in capsule dose form per day for four days. Eggs and feces were collected each day for analysis. Twenty-four hours following the final dosing, the four birds were sacrificed and samples of kidneys, liver, heart, white meat, dark meat, fat, and skin were analyzed. On average, 29% of the daily dose was excreted by birds as malathion daily in feces through the study period. Radiolabelled-malathion was not detected in any of the organs tested (method detection limit was ≤ 0.01 mg ai/kg ww). Similarly, malathion metabolites (malaoxon, MMCA, MDCA, and desmethyl malathion) were not detected, or detected at levels ≤ 0.01 mg ai/kg ww. The results suggest that malathion is rapidly metabolized and excreted in leghorn hens.

A half-life of 0.143 days was assumed for this assessment based on data derived from Cannon et al. (1993 [MRID 42715401]). Assuming an overall first-order removal rate, a parent and oxon first-order metabolism half-life of 3.54 hours and the elimination half-life of 4.93 days results in an overall removal rate of -0.202 h^{-1}. That overall removal rate is equal to a half-life of 3.44 hours, or 0.143 days.

3.1.12 Diet

Kirtland's warblers forage primarily on arthropods during the breeding season, although blueberries become a significant part of the diet when they ripen in August (Mayfield, 1960; Walkinshaw, 1983; Fussman, 1997; Deloria-Scheffield et al., 2001). Based on fecal samples collected from June to September, 1995-1997, Deloria-Scheffield et al. (2001) determined that arthropods from 16 families were in the Kirtland's warbler diet. In the 202 fecal samples collected, there were 390 observations of arthropods and 85 observations of blueberries (Note: there can be multiple observations of dietary items in a fecal sample). This suggests a diet of at least 80% arthropods. Mayfield (1960) also noted that about 80% of foraging observations were on jack pines during the breeding season. He further observed that arthropods comprised nearly all of the diet, likely because most observations were from earlier in the breeding season prior to blueberries ripening in August (see also Walkinshaw, 1983; Fussman, 1997). Based on the available information we assumed a betapert distribution for proportion of invertebrates in the diet with a most likely value of 0.88, a minimum of 0.6 and a maximum of 1. In the breeding area model, a value is randomly chosen from the betapert distribution for each simulated bird. The remainder of the diet for that simulated bird is then assumed to be blueberries.

3.1.13 Averaging Period for Chronic Exposure

For malathion, regressed ovaries and reduced egg hatch were the most important factors leading to reduced reproductive success in the chronic northern bobwhite reproduction study used to generate the chronic effects metrics for this assessment (Beavers et al., 1995 [MRID 43501501]). See Section 5 for additional details.

To be conservative, a 21-d average total daily intake (TDI) was calculated for each day in the 60-d model runs for chronic exposure. The maximum 21-d average TDI that occurred during the 60-d simulation was compared to the NOEL for each bird in each simulation.

3.2 Results of Breeding Area Exposure Modeling

The results of the acute and chronic simulations of Kirtland's warblers potentially exposed to malathion in the breeding area (Table 3-7 and Table 3-8, respectively) illustrate some of the major trends that emerged from the analyses. These include:

- Acute and chronic exposure estimates were quite variable among individual Kirtland's warblers for each of the use patterns considered. For most of the use patterns, over 50% of individuals did not receive any exposure, either acute or chronic (Table 3-7 and Table 3-8). Lack of exposure was the direct result of nests being greater than 3 km from the closest edge of a treated field. However, for each use pattern, at least 5% of individuals were exposed.

- For every use pattern, aerial application produced acute and chronic exposure estimates that were often an order of magnitude greater than the corresponding ground application estimates. Spray drift is much greater with aerial application compared to ground application which explains the results.

- The use pattern with the highest rate of application (i.e., Christmas tree) did not produce the highest exposure estimates. In the case of Christmas trees, few treated areas in that crop class are located within 3 km of Kirtland's warbler nests thus limiting exposure even with a high application rate. Conversely, alfalfa has a relatively low application rate, yet that use pattern produced the highest exposure estimates. This result can likely be attributed to the closer proximity of the use pattern to Kirtland's warbler nests.

Table 3-7 Acute peak body burdens (mg ai/kg bw) of MAL in Kirtland's warblers during the breeding season

Use Pattern	***Mean***	***1st %ile***	***5th %ile***	***25th %ile***	***Median***	***75th %ile***	***95th %ile***	***99th %ile***
Alfalfa – 1.25 lb/A 2X @ 14-d interval, aerial	0.238	0	0	0.0371	0.111	0.258	0.877	2.17
Alfalfa – 1.25 lb/A 2X @ 14-d interval, ground	0.0352	0	0	0.0057	0.0169	0.0401	0.127	0.292
Apple – 1.25 lb/A 2X @ 7-d interval, aerial	0.0408	0	0	0	0	0	0.239	0.75
Apple – 1.25 lb/A 2X @ 7-d interval, airblast	0.0059	0	0	0	0	0	0.0310	0.109
Apple – 1.25 lb/A 2X @ 7-d interval, ground	0.0135	0	0	0	0	0	0.078	0.277
Christmas tree – 3.2 lb/A 2X @ 7-d interval, aerial	0.146	0	0	0	0	0	0.767	2.33
Christmas tree – 3.2 lb/A 2X @ 7-d interval, ground	0.0235	0	0	0	0	0.000	0.13	0.42

Table 3-7 Acute peak body burdens (mg ai/kg bw) of MAL in Kirtland's warblers during the breeding season								
Use Pattern	***Mean***	***1st %ile***	***5th %ile***	***25th %ile***	***Median***	***75th %ile***	***95th %ile***	***99th %ile***
Corn – 1 lb/A 2X @ 7-d interval, aerial	0.0196	0	0	0	0.037	0.141	0.529	1.14
Corn – 1 lb/A 2X @ 7-d interval, ground	0.126	0	0	0	0.00538	0.021	0.0819	0.189
Dry bean – 0.61 lb/A 2X @ 7-d interval, aerial	0.0337	0	0	0	0	0	0.19	0.492
Dry bean – 0.61 lb/A 2X @ 7-d interval, ground	0.00503	0	0	0	0	0	0.0265	0.0791
Potato – 1.56 lb/A 2X @ 7-d interval, aerial	0.135	0	0	0	0	0.128	0.627	1.63
Potato – 1.56 lb/A 2X @ 7-d interval, ground	0.0208	0	0	0	0	0.0195	0.0982	0.246
Oats – 1 lb/A 2X @ 7-d interval, aerial	0.0824	0	0	0	0	0.0735	0.396	1.02
Oats – 1 lb/A 2X @ 7-d interval, ground	0.012	0	0	0	0	0.0106	0.0592	0.145

Table 3-8 Chronic rolling average total daily intake (mg ai/kg bw/d) of MAL in Kirtland's warblers during the breeding season								
Use Pattern	***Mean***	***1st %ile***	***5th %ile***	***25th %ile***	***Median***	***75th %ile***	***95th %ile***	***99th %ile***
Alfalfa – 1.25 lb/A 2X @ 14-d interval, aerial	0.157	0	0	0.0292	0.0826	0.180	0.553	1.240
Alfalfa – 1.25 lb/A 2X @ 14-d interval, ground	0.0232	0	0	0.00442	0.0123	0.0272	0.0799	0.177
Apple – 1.25 lb/A 2X @ 7-d interval, aerial	0.0275	0	0	0	0	0	0.172	0.50
Apple – 1.25 lb/A 2X @ 7-d interval, airblast	0.00384	0	0	0	0	0	0.0222	0.073
Apple – 1.25 lb/A 2X @ 7-d interval, ground	0.00917	0	0	0	0	0	0.0539	0.183
Christmas tree – 3.2 lb/A 2X @ 7-d interval, aerial	0.0987	0	0	0	0	0	0.551	1.48
Christmas tree – 3.2 lb/A 2X @ 7-d interval, ground	0.0156	0	0	0	0	0.000	0.089	0.25
Corn – 1 lb/A 2X @ 7-d interval, aerial	0.0131	0	0	0	0.029	0.102	0.354	0.737
Corn – 1 lb/A 2X @ 7-d interval, ground	0.0853	0	0	0	0.00419	0.0155	0.0544	0.118
Dry bean – 0.61 lb/A 2X @ 7-d interval, aerial	0.0228	0	0	0	0	0	0.13	0.315
Dry bean – 0.61 lb/A 2X @ 7-d interval, ground	0.00341	0	0	0	0	0	0.0184	0.0499
Potato – 1.56 lb/A 2X @ 7-d interval, aerial	0.0907	0	0	0	0	0.096	0.42	1.01
Potato – 1.56 lb/A 2X @ 7-d interval, ground	0.0139	0	0	0	0	0.0146	0.0663	0.157

Table 3-8 Chronic rolling average total daily intake (mg ai/kg bw/d) of MAL in Kirtland's warblers during the breeding season								
Use Pattern	***Mean***	***1st %ile***	***5th %ile***	***25th %ile***	***Median***	***75th %ile***	***95th %ile***	***99th %ile***
Oats – 1 lb/A 2X @ 7-d interval, aerial	0.0554	0	0	0	0	0.0555	0.26	0.652
Oats – 1 lb/A 2X @ 7-d interval, ground	0.00811	0	0	0	0	0.00818	0.0401	0.0916

3.3 Sensitivity Analysis for Breeding Area Model

The sensitivity analyses for the Kirtland's warbler breeding area model for malathion relied on "what if" analyses using a "one-at-a-time" design. Two baseline scenarios, a low and a high exposure scenario, were used in the sensitivity analyses for acute and chronic exposure (Table 3-9). The low exposure scenario was for Kirtland's warblers in proximity to apple orchards treated with malathion two times at a rate of 1.25 lb ai/A with a 7-d interval via airblast. The high exposure scenario was for malathion aerially applied two times to alfalfa fields with an application rate of 1.25 lb ai/A and a 14-d interval. Alfalfa fields occur in closer proximity to Kirtland's warbler breeding areas far more often than do apple orchards. For each of the scenarios, one variable was altered at a time to explore how use of plausible upper and lower bounds influenced the output variables, i.e., mean acute and chronic exposure (Table 3-10).

Table 3-9 Baseline input parameter values for breeding area model sensitivity analyses		
Variable	***Parameter Value(s)***	***Units***
Residue Half-life - Invertebrates	2.31	d
Residue Half-life - Blueberries	5.06	d
Nomogram - Invertebrates	Mean=15.67, SD=28.58	mg ai/kg ww/lb ai/A
Nomogram - Blueberries	Mean=0.916, SD=1.145	mg ai/kg ww/lb ai/A
Model Time Step	0.16667	hrs
Bird Sex	Males and Females in 1:1 Ratio	
Body Weight - Adult Females	Mean=14.3, SD=1.18	g
Body Weight - Adult Males	Mean=13.6, SD=0.59	g
Proportion Diet Blueberries	Mean=0.12, Minimum=0, Maximum=0.4	
Territory Size - Diameter	Mean=283, Minimum=229, Maximum=329	m
Nest Location	Median=0.5, Minimum=0.07, Maximum=0.93	
Foraging Distance - Rate	0.05	
Elimination Half-life	0.143	d

Table 3-10 Input values for sensitivity analyses with low and high exposure scenarios for the breeding area model		
Variable	***Parameter Values***	***Notes***
Residue Half-life – Invertebrates (d)	Minimum=0.96 Maximum=4.46	Minima are lowest available values. Maxima are highest available values.
Residue Half-life – Blueberries (d)	Minimum=0.823 Maximum=12.5	

Table 3-10 Input values for sensitivity analyses with low and high exposure scenarios for the breeding area model

Variable	***Parameter Values***	***Notes***
Nomogram – Invertebrates (mg ai/kg ww/lb ai/A)	MAL-specific 5^{th} %ile=0.833 MAL-specific 95^{th} %ile=16.4 EPA Mean=65 EPA Upper=94	MAL-specific percentiles determined from baseline input values assuming an underlying lognormal distribution. EPA values are from Table 3-12 in the draft biological evaluation for MAL.
Nomogram – Blueberries (mg ai/kg ww/lb ai/A)	MAL-specific 5^{th} %ile=0.26 MAL-specific 95^{th} %ile=5 EPA Mean=7 EPA Upper=15	
Model Time Step (hrs)	1 24	EPA's Terrestrial Investigation Model has an hourly time step and MCnest has a daily time step.
Bird Sex	Males Only Females Only	
Proportion Diet - Blueberries	Minimum=0 Maximum=0.4	Point estimates were used for each variable instead of the betapert distributions used in the baseline analyses.
Territory Diameter (m)	Minimum=229 Maximum=329	
Nest Location	Minimum=0.07 Maximum=0.93	
Foraging Distance	Minimum Rate=0.025 Maximum Rate=0.4	Rate of 0.025 produces a max foraging distance of close to 200 m, which is about as far as warblers could travel and remain within their territories. Rate of 0.4 produces a max foraging distance of close to 10 m, the distance from the nest wherein warblers gather most of their food (see Mayfield, 1960).

The results of the sensitivity analyses indicate that choice of input parameter value for the mean nomogram for invertebrates and nest location has large impacts on the acute and chronic exposure metrics (Table 3-11 and Table 3-12). As expected, as the nomogram value for invertebrates increased, exposure increased. The use of malathion-specific nomograms led to significant reductions in predicted exposure to Kirtland's warblers compared to the use of the standard mean and upper nomogram values used by EPA. Increasing the value of the mean nomogram for blueberries had a negligible impact on estimated acute and chronic exposure indicating that invertebrates are the dominant dietary contributor to overall exposure to the Kirtland's warbler. Nest location was an important variable because nests located further from the treated area receive less spray drift.

Several other input variables had a moderate influence on estimated acute and chronic exposure including the residue half-life in invertebrates, and model time step (Table 3-11 and Table 3-12). As expected, there was a positive relationship between acute and chronic exposure and residue half-life in invertebrates. Increasing the time step to a daily time step led to increased estimates for acute and chronic exposure likely because the longer time step did not allow for dissipation over the course of the day on any of the day of application (the days when peak exposure would be expected).

Table 3-11 Results of sensitivity analysis with low exposure scenario (i.e., apples 2X @ 1.25 lb ai/A, 7-d interval via airblast) for breeding area model

Variable	*Parameter*	*Value*	*Mean Peak Body Burden (mg ai/kg bw)*	*Mean Peak 21-day Average TDI (mg/kg bw/d)*
Residue Half-life – Invertebrates (d)	Minimum	0.96	0.00519	0.00168
	Baseline	2.31	0.00628	0.00415
	Maximum	4.46	0.00660	0.00690
Residue Half-life – Blueberries (d)	Minimum	0.823	0.00613	0.00403
	Baseline	5.06	0.00628	0.00415
	Maximum	12.5	0.00596	0.00400
Nomogram – Invertebrates (mg ai/kg ww/lb ai/A)	MAL 5th %ile	0.833	0.00028	0.00021
	Baseline	15.67	0.00628	0.00415
	MAL 95th %ile	16.4	0.00615	0.00410
	Kenaga Mean	65	0.0197	0.0163
	Kenaga Upper	94	0.0283	0.0244
Nomogram – Blueberries (mg ai/kg ww/lb ai/A)	MAL 5th %ile	0.26	0.00585	0.00385
	Baseline	0.916	0.00628	0.00415
	MAL 95th %ile	5	0.00638	0.00440
	Kenaga Mean	7	0.00637	0.00450
	Kenaga Upper	15	0.00739	0.00553
Model Time Step (hrs)	Baseline	0.1667	0.00628	0.00415
	Hourly	1	0.00646	0.00356
	Daily	24	0.0395	0.00771
Bird Sex	Males Only		0.00596	0.00596
	Baseline (1:1 M to F)		0.00628	0.00415
	Females Only		0.00588	0.00389
Proportion Diet - Blueberries	Minimum	0	0.00660	0.00426
	Baseline Distribution		0.00628	0.00415
	Maximum	0.4	0.00438	0.00307
Territory Diameter (m)	Minimum	229	0.00778	0.00510
	Baseline Distribution		0.00628	0.00415
	Maximum	329	0.00477	0.00317
Nest Location	Minimum	0.07	0.0323	0.0211
	Baseline Distribution		0.00628	0.00415
	Maximum	0.93	0.00173	0.00115
Foraging Distance	Minimum	0.025	0.00641	0.00404
	Baseline	0.05	0.00628	0.00415
	Maximum	0.4	0.00522	0.00360

Table 3-12 Results of sensitivity analysis with high exposure scenario (i.e., alfalfa 2X @ 1.25 lb ai/A, 14-d interval via aerial application) for breeding area model

Variable	*Parameter*	*Value*	*Mean Peak Body Burden (mg ai/kg bw)*	*Mean Peak 21-day Average TDI (mg/kg bw/d)*
Residue Half-life – Invertebrates (d)	Minimum	0.96	0.206	0.0679
	Baseline	2.31	0.232	0.152
	Maximum	4.46	0.249	0.262
Residue Half-life – Blueberries (d)	Minimum	0.823	0.243	0.156
	Baseline	5.06	0.232	0.152
	Maximum	12.5	0.234	0.154
Nomogram – Invertebrates (mg ai/kg ww/lb ai/A)	MAL 5th %ile	0.833	0.0177	0.0115
	Baseline	15.67	0.232	0.152
	MAL 95th %ile	16.4	0.235	0.155
	Kenaga Mean	65	0.745	0.616
	Kenaga Upper	94	1.01	0.883
	MAL 5th %ile	0.26	0.226	0.147

Table 3-12 Results of sensitivity analysis with high exposure scenario (i.e., alfalfa 2X @ 1.25 lb ai/A, 14-d interval via aerial application) for breeding area model

Variable	*Parameter*	*Value*	*Mean Peak Body Burden (mg ai/kg bw)*	*Mean Peak 21-day Average TDI (mg/kg bw/d)*
Nomogram – Blueberries (mg ai/kg ww/lb ai/A)	Baseline	0.916	0.232	0.152
	MAL 95th %ile	5	0.235	0.160
	Kenaga Mean	7	0.24	0.168
	Kenaga Upper	15	0.255	0.192
Model Time Step (hrs)	Baseline	0.1667	0.232	0.152
	Hourly	1	0.264	0.157
	Daily	24	1.37	0.322
Bird Sex	Males Only		0.231	0.231
	Baseline (1:1 M to F)		0.232	0.152
	Females Only		0.229	0.150
Proportion Diet - Blueberries	Minimum	0	0.247	0.160
	Baseline Distribution		0.232	0.152
	Maximum	0.4	0.199	0.134
Territory Diameter (m)	Minimum	229	0.286	0.188
	Baseline Distribution		0.232	0.152
	Maximum	329	0.204	0.133
Nest Location	Minimum	0.07	0.650	0.425
	Baseline Distribution		0.232	0.152
	Maximum	0.93	0.095	0.0614
Foraging Distance	Minimum	0.025	0.241	0.155
	Baseline	0.05	0.232	0.152
	Maximum	0.4	0.225	0.147

4.0 EXPOSURE ASSESSMENT – MIGRATION MODEL

The migration model simulates 10,000 Kirtland's warblers during the course of their 13- to 23-day migration (Ewert et al., 2012) between their breeding area and the Bahamas. The model has an hourly time step and can be used to simulate spring or fall migration. Typically, Kirtland's warblers have only one to three stopovers during migration in which they actively forage for an extended duration (typically one day but can be up to six days; Petrucha et al., 2013). In the model, two stopovers are assumed, each of which is assumed to occur on randomly chosen days during the first half and during the second half of the migration period. The migration duration and the duration of each stopover are randomly determined values. The vast majority of stopovers will be in habitats that cannot be treated with malathion (mostly scrub-shrub vegetation) (Petrucha et al., 2013). However, on occasion warblers may stop over in orchards that could be treated with MAL (e.g., apples in the Northeast, peaches in Georgia, oranges in Florida). Thus, during each stopover, the model randomly determines whether the simulated bird is in an orchard, whether that orchard has been treated with MAL, and, if treated, the time since the last application occurred. This information is used to determine dietary concentrations to which each bird is exposed during the stopover. The acute exposure metric (i.e., peak body burden) is determined using the same approach as in the breeding area model. Chronic exposure is not estimated in the migration model because of the limited number of short stopovers that occur during migration. In the migration model, we simulated multiple use patterns because each bird could encounter different types of orchards during a migration. The conceptual model for the migration model is shown in Figure 4-1.

To calculate dose at each hourly time step, food intake rate is multiplied by dietary concentration and the proportion of the dietary item for each item in the diet. Food intake rate is based on an allometric relationship for passerine birds (Nagy et al., 1999). Each individual body mass used as an input to the allometric relationship is randomly sampled from body weight distributions specific to males, females, or combined sexes (i.e., assuming 1:1 ratios of males to females) of the Kirtland's warbler. In this assessment, we assumed a 1:1 ratio of males to females. Thus, the dose for an individual bird for a given time step is:

$$D_{TS} = PDI \times FIR \times \sum_{i=1}^{2} C_i \, x \, P_i \qquad \text{Equation 4-1}$$

where,

D_{TS} is the time step (TS = 1 hour) dose (mg ai/kg bw/hour),
PDI is proportion of the total daily food and water intake occurring during the hourly time step;
FIR is food intake rate (kg ww/kg bw/d);
C_i is concentration in the i^{th} dietary item (mg ai/kg bw); and
P_i is proportion of the i^{th} dietary item in the diet.

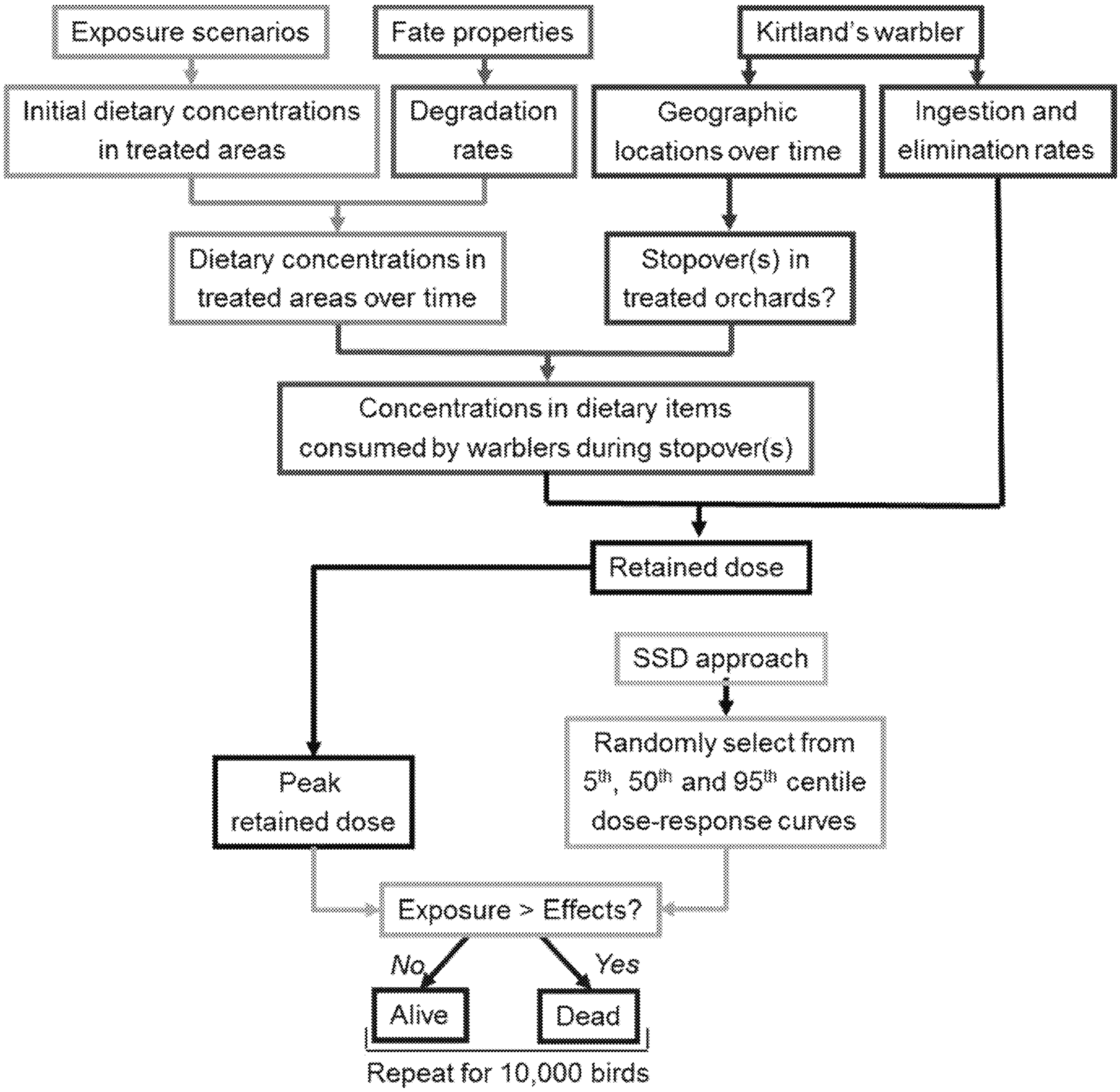

Figure 4-1. Components of the migration model for the Kirtland's warbler.

The amount of MAL retained by a bird (i.e., body burden) from one time step to the next is governed by the rate of metabolism:

$$RD_t = D_{TS} + RD_{t-1}\ x\ f_{retained} \qquad \text{Equation 4-2}$$

where,

RD is retained dose (mg ai/kg bw);

D_{TS} is the dose from the current time step (mg ai/kg bw/hour);
t is the current time step;
t-1 is the previous time step; and
$f_{retained}$ is the fraction of MAL retained in the bird after accounting for metabolism and elimination of the compound.

Once *RD* has been calculated for each hour in the migration model (25 d x 24 hr/d = 600 hourly time steps), the model searches for the peak hourly retained dose (i.e., body burden) to determine acute exposure. The peak body burden is compared to the acute effects metrics to determine if the bird is adversely affected (Figure 4-1).

The approach used in the migration model to determine the fate of an individual bird for an acute exposure is the same as that used by EPA (2005), Moore et al. (2014) and was previously described in Section 3.1.

Several factors determine the concentrations of MAL to which Kirtland's warblers may be exposed during the course of their migration. As noted above, the model must first determine where the bird has stopovers, whether one or both stopovers occurs in a habitat that could be treated with MAL (i.e., orchards, see below), and the length of the stopovers. If a stopover occurs in an orchard, the model determines type of orchard based on geographic location of the bird, and estimates concentrations of MAL in dietary items at the time the bird is there. The latter is a function of probability that the orchard has been treated, and, if applicable, application rate and time since the application took place.

Section 3.1 describes the equations and inputs used in the MAL exposure modeling conducted for Kirtland's warbler during spring and fall migrations. Subsequently, we provide the exposure analysis results and the results of a sensitivity analysis.

4.1 Input Parameters for Exposure Component of Migration Model

4.1.1 Duration of Migration

Ewert et al. (2012) color-banded five male Kirtland's warblers and determined the duration of their spring migration from Eleuthera in the Bahamas to their breeding habitats in Michigan. The average duration of spring migrations for these five individuals was 15.8 d and the range was 13 to 23 d. Although the dataset has a limited sample size, we used these data to parameterize a betapert distribution with a mean, minimum and maximum of 15.8, 13 and 23 d. For each bird in a migration simulation, duration of migration was determined by random sampling from the betapert distribution.

4.1.2 Stopover Timing

Although the number of stopovers that occurs during spring and fall migration has not been determined for Kirtland's warblers, they do have occasional stopovers during which they forage actively for food (Petrucha et al., 2013). Given the duration of migration and the distance travelled, the number of stopovers is likely to vary from at least one (Bocetti et al., 2014) to perhaps several. When birds depart for spring and fall migrations, they do so with a layer of subcutaneous fat sufficient to enable them to go periods of time without foraging (Rockwell, 2013). For the migration model, we assumed that each bird had two stopovers per migration. We further assumed that stopovers would occur during the first half and the second half of the trip. The exact date of each stopover was determined by randomly sampling from a discrete uniform distribution that bracketed the durations of each half migration.

4.1.3 Number of Days at Each Stopover

Petrucha et al. (2013) reviewed available historical records since the late 19th century of Kirtland warbler observations during spring and fall migrations. The database included 562 records of which Petrucha et al. (2013) determined that 425 were considered acceptable. The majority of these records (n=372) determined stopover durations for males and females during spring and fall migrations. Stopover durations were consistent between the sexes and seasons and thus we used the cumulative results in the migration model. Stopover duration varied from 1-6 days (with one outlier at 12 days, which was not included in the model) with 90% of the observations indicating a stopover duration of one day. Stopover durations of two and three days occurred in 4.6 and 3.2% of the observations, respectively. Longer stopover durations were infrequent. For this variable, we created an empirical distribution using the cumulative results listed in Table 7 of Petrucha et al. (2013). For each stopover, the empirical distribution was sampled to determine stopover duration.

4.1.4 Probability that a Stopover Occurs in an Orchard

The Petrucha et al. (2013) study also determined the stopover habitats by sex and season for the Kirtland's warbler (see Table 4 in the citation). The patterns were again consistent across sex and season. The vast majority of stopovers occurred in habitats similar in structure to the habitats found on the breeding and wintering grounds. The habitat most often used by migrant Kirtland's warblers is shrub/scrub (82.4% of birds) and the remainder quite likely had somewhat similar structures (e.g., woodland areas, parks, residential areas, orchards). Of these habitats, only orchards have the potential to be treated with MAL according to the labels (Appendix A). Orchard stopovers are infrequent and only occurred in 1.6% of the observations in Petrucha et al. (2013; see Table 4). No Kirtland's warblers have been observed in orchard habitats during migration since 1900 despite the fact that observations of Kirtland's warblers have been far more frequent in recent decades (see Appendices 1 and 2 in Petrucha et al., 2013). For each stopover in the migration model, we determined whether the stopover habitat was an orchard by sampling from a binomial distribution with a sample size of one and probability of 0.016 (= 1.6%).

4.1.5 Crop Scenarios

The migratory pathway for Kirtland's warbler between the breeding and wintering areas is quite broad, although they migrate primarily east of the Mississippi River (Petrucha et al., 2013). In determining possible exposure scenarios for migrant Kirtland's warblers, we divided the migration pathway into three zones based on type of orchard most likely to be encountered. The Florida zone includes citrus orchards and spans an approximate distance of 370 miles from Florida City (the southernmost location for citrus orchards) to the northern edge of Marion County (the approximate northern boundary for citrus crops). The Southeast zone includes peach orchards, the primary orchard crop in this zone, and spans a distance of 370 miles from the southern edge of Georgia to Charlotte, NC, the northern edge of the peach growing area. Finally, the Northeast/Northcentral zone includes many of the apple-growing states and roughly spans a distance of 856 miles from Charlotte, North Carolina to Traverse City, Michigan. We chose to model oranges, peaches, and apples because these are the important orchard crops east of the Mississippi that may be treated with MAL. Thus, the exposure scenarios in the migration model err to the conservative side.

In the migration model, the proportions of the migration occurring in the Florida, Southeast, and Northeast/Northcentral zones were specified as 0.24, 0.205 and 0.555 which were calculated by dividing the estimated diameter of each zone (see preceding paragraph) by the total length of the migration. At each day, the model determines in which zone the migrant will be found. If, for example, the migrant is in the Florida zone, the model determines: (1) whether a stopover occurred there and on what day(s), (2) whether the stopover was in an orchard, and (3) whether the orchard had been treated with MAL prior to arrival of the migrant. For the latter, the probabilities of the orchard crop being treated with MAL were determined by taking the upper bounds from the ranges collected from a query of the GfK Kynetec database for crop treatment (Gfk Kynetec, 2016). The upper bounds for percent orchard crops treated with MAL are 8.9% for oranges, 48% for peaches, and 0.59% for apples. These values were used in binomial distributions (with a sample size of one) for each crop to determine whether an orchard with a migrant had been recently treated with MAL.

Birds can pass through an orchard at different times following treatment with MAL. To determine time since MAL treatment, a discrete uniform distribution was sampled. In the case of orange orchards, the range specified in the discrete uniform distribution was zero (i.e., migrant arrives day of application) to 30 days (i.e., migrant arrives 30 days after application) because only one foliar treatment is permitted per season. For peaches, the discrete uniform distribution ranges from zero to ten days because there can be three MAL applications per season with a minimum eleven-day interval. For apples, the discrete uniform distribution ranges from zero to fifteen days because there can be two MAL applications per season. The parameterizations of the discrete uniform distributions are worst case, as applications could occur in other months of the growing season.

To be conservative, all orchards were assumed to be treated at the maximum application rate permitted on the malathion labels (4.5 lb ai/A for oranges, 3 lb ai/A for peaches, 1.25 lb ai/A for apples) with the maximum number of applications (3 for peaches, 2 for apples, 1 for oranges) and minimum retreatment interval (7 days for apples, 11 days for peaches). Applications can occur during spring and fall migrations.

4.1.6 Dietary Concentrations

For birds that do have a stopover in an orchard recently treated with MAL, dietary concentrations in invertebrates and small berries need to be estimated. In the migration model, initial concentrations at the beginning of the stopover are determined using the MAL-specific nomograms for foliage-dwelling invertebrates and blueberries described in Section 3.1 adjusted for the time elapsed between application and arrival of the migrant. The dissipation rates used for this adjustment are the same as those described in Section 3.1 for invertebrates and blueberries. The dietary concentrations decline according to the dissipation rates for the duration of the stopover.

4.1.7 Peak Body Burden

As in the breeding area model, peak body burden is estimated for each Kirtland's warbler migrant. Hourly body burden is calculated using the same approach and inputs as described in Chapter 3 assuming that migrants have a sex ratio of 1:1 males to females. For each simulated bird, the peak body burden that occurred during the migration period is the exposure metric used to determine the ultimate fate of the bird (alive or dead).

4.2 Results of Migration Exposure Modeling

The results of the migration modeling for Kirtland' warblers potentially exposed to MAL are shown in Table 4-1. The results indicate that the vast majority of Kirtland's warblers are never exposed to MAL, primarily because of the infrequency of stopping over in orchards that have been recently treated with MAL.

Table 4-1 Peak body burdens of MAL in Kirtland's warblers during spring and fall migrations

Season	***Peak Body Burden (mg ai/kg bw)***							
	Mean	***1st %ile***	***5th %ile***	***25th %ile***	***Median***	***75th %ile***	***95th %ile***	***99th %ile***
Spring	0.00275	0	0	0	0	0	0	0
Fall	0.00381	0	0	0	0	0	0	0

4.3 Sensitivity Analyses for Migration Model

The sensitivity analyses for the Kirtland's warbler migration model for MAL relied on "what if" analyses using a "one-at-a-time" design, as was the case with the breeding area model. The baseline scenario (Table 4-2) used in the sensitivity analyses for the migration model was the same as the exposure scenario used in the spring migration model used to generate the results in Table 4-1. For the sensitivity analyses, one variable was altered at a time to explore how use of plausible upper and lower bounds influenced the output variables, i.e., mean acute exposure (Table 4-3).

Table 4-2 Baseline input parameter values for migration model sensitivity analyses		
Variable	***Parameter Value(s)***	***Units***
Apple Application Rate	1.25	lb ai/A
Peach Application Rate	3	
Orange Application Rate	4.5	
Probability of Treatment - Apple	0.0059	
Probability of Treatment - Peach	0.48	
Probability of Treatment - Orange	0.089	
Number of Treatments per Month - Apple	2	
Number of Treatments per Month - Peach	3	
Number of Treatments per Month - Orange	1	
Spring or Fall Migration	Spring Migration	
Proportion Migration in Apple States	0.536	
Proportion Migration in Pecan States	0.232	
Proportion Migration in Orange State (FL)	0.232	
Residue Half-life - Invertebrates	2.31	d
Residue Half-life - Blueberries	5.06	
Nomogram - Invertebrates	Mean=15.67, SD=28.58	mg ai/kg ww/lb ai/A
Nomogram - Blueberries	Mean=0.916, SD=1.145	
Bird Sex	Males and Females in 1:1 Ratio	
Body Weight - Adult Females	Mean=14.3, SD=1.18	g
Body Weight - Adult Males	Mean=13.6, SD=0.59	g
Proportion Diet Berries	Mean=0.12, Minimum=0, Maximum=0.4	
Duration of Migration Period	Mean=15.8, Minimum=13, Maximum=23	d
Duration of Extended Stopover	Probability 1 0.900269542 2 0.045822102 3 0.032345013 4 0.005390836 5 0.005390836 6 0.010781671	d
Probability of Foraging in an Orchard	0.016	
Time Since Treatment (All Orchards)	Randomly Chosen From Discrete Uniform Distributions with Ranges [0,30] for Oranges, [0,10] for Peaches, and [0,15] for Apples	d
Elimination Half-life	0.143	d
Number of Trials	10,000	

Table 4-3 Input values for sensitivity analyses with the migration model		
Variable	***Parameter Values***	***Notes***
Probability of Treatment	Maxima: All=1	Maxima assume that all orchards are treated with MAL.
Number of Treatments per Month	All=1	This is the minimum number of treatments per month per crop except for the trivial case of no treatments at all.
Residue Half-life – Invertebrates (d)	Minimum=0.96 Maximum=4.46	Minima are lowest available values, invertebrates from Brown et al. (2006). Maxima are highest available values, invertebrates from Frese et al., (2008). See Supplemental Information in Moore et al. (2014b).
Residue Half-life – Berries (d)	Minimum=0.823 Maximum=12.5	
Nomogram – Invertebrates (mg ai/kg ww/lb ai/A)	MAL-specific 5th %ile=0.833 MAL-specific 95th %ile=16.4 EPA Mean=65 EPA Upper=94	MAL-specific percentiles determined from baseline input values assuming an underlying lognormal distribution. EPA values are from Table 3-12 in the draft biological evaluation for MAL.

Table 4-3 Input values for sensitivity analyses with the migration model		
Variable	***Parameter Values***	***Notes***
Nomogram – Berries (mg ai/kg ww/lb ai/A)	MAL-specific 5th %ile=0.26 MAL-specific 95th %ile=5 EPA Mean=7 EPA Upper=15	
Bird Sex	Males Only Females Only	
Proportion Diet - Berries	Minimum=0 Maximum=0.4	Point estimates were used for each variable instead of the distributions used in the baseline analyses.
Duration of Migration Period (d)	Minimum=13 Maximum=23	
Duration of Stopover (d)	Minimum=1 Maximum=6	
Probability of Foraging in an Orchard	Maximum=1	Assumes that every stopover occurs in an orchard.
Time Since Treatment – All Orchards (d)	Minimum=0	Assumes all bird stopovers in orchards occur on day of MAL application.

The results of the sensitivity analyses indicated for all variables, except probability of foraging in an orchard, that Kirtland's warblers were rarely exposed to MAL during spring migration. As a result, estimates of mean body burden were very low, but somewhat unstable (i.e., estimates had high variation between runs of the same scenario). For this reason, we do not present the results of the sensitivity analysis for the migration model.

The mean body burden in Kirtland's warblers increased from 0.00493 mg ai/kg bw that was observed in repeated runs of the baseline spring migration model (assuming probability of foraging in an orchard is 0.016) to 0.0711 mg ai/kg bw when all foraging stopovers were assumed to be in orchards (i.e., p = 1). No other input variable in the sensitivity analysis had anywhere near as dramatic an impact on estimated mean body burden.

5.0 EFFECTS ASSESSMENT

The following sections describe how the acute and chronic effects metrics were derived. There were an insufficient number of tested species to permit development of a SSD for both acute and chronic toxicity data.

5.1 Acute Effects Metrics

There is an insufficient number of studies to derive an acute SSD for malathion. Given the lack of acute toxicity studies for birds, we used a conservative approach and selected an LD50 from the most sensitive species tested to date, i.e., the ring-necked pheasant (*Phasianus colchicus*). In a 14-day study (Hubbard and Beavers, 2012a [MRID 48963307]), the LD50 was calculated to be 136 mg ai/kg bw. This LD50 was used, along with the probit slope of 6.5543, to derive a dose-response curve.

5.2 Chronic Effects Metrics

There is an insufficient number of studies to derive a chronic SSD for malathion. Given the lack of chronic toxicity studies for birds, we used a conservative approach and derived a NOEL from the most sensitive species tested to date, i.e., the northern bobwhite (*Colinus virginianus*). In a 21-week dietary exposure study (Beavers et al., 1995 [MRID 43501501)], regressed ovaries and reduced egg hatch were observed at 350 mg ai/kg diet but not at 110 mg ai/kg diet. This NOEL corresponds with a value of 12.6 mg ai/kg bw/d which was used as the threshold for chronic toxicity in the Kirtland's warbler assessment.

6.0 RISK CHARACTERIZATION

In the draft Biological Evaluation for malathion, EPA (2016) conducted probabilistic risk analyses for 13 listed bird species exposed to MAL, including the Kirtland's warbler. Their probabilistic avian assessments relied on two models: the Terrestrial Investigation Model or TIM (version 3.0 beta) and the Markov Chain nest productivity model or MCnest. TIM is a multiple exposure route model used to estimate avian mortality from acute pesticide exposure. During a TIM simulation, birds are assumed to use the treated field and edge habitat to meet their requirements for food and water where they may also receive pesticide exposure via dermal and inhalation routes. MCnest estimates the chronic impacts of pesticides on the reproductive success of bird populations (i.e., fecundity). MCnest relies on the exposure estimates generated by TIM. In estimating chronic avian risk, MCnest includes adverse effects to survival, reproduction, growth and behavior along with life history characteristics of the listed species under investigation. In the case of Kirtland's warbler exposed to MAL, TIM and MCnest only considered effects that could occur during the breeding season. EPA (2016) did not model risks posed by MAL during spring and fall migration.

The TIM/MCnest models differ from the Kirtland's warbler breeding area model described in Chapter 3 in several fundamental respects:

- TIM and MCnest assume that the Kirtland's warbler is an edge species that will have a low foraging frequency on treated fields, e.g., pasture. For this variable, EPA (2016) assumed a betapert distribution with a minimum of 0 (incorrectly stated as 0.1 in Table 14 in Appendix 4-7 Supplemental Information), a mean of 0.1 (incorrectly stated as 0 in Table 14 in Appendix 4-7 Supplemental Information) and a maximum of 0.2. As described in Section 2.1, however, Kirtland's warblers forage exclusively within their territories located in young jack pine forests during the breeding season (Probst, 1988; Probst and Weinrich, 1993; Fussman, 1997; FWS, 1985, 2012). Thus, they would not be exposed to MAL in dietary items located in treated areas such as pastures. As a result, the Kirtland's warbler breeding model used in this assessment assumed that dietary exposure could only be the result of spray drift from treated areas to Kirtland's warbler breeding habitats.
- As discussed in Section 3.1, the nomograms used in the Kirtland's warbler breeding area model were based on MAL-specific field studies. TIM/MCnest, however, relied on generic nomograms for terrestrial invertebrates and small berries which were much higher than the corresponding MAL-specific nomograms (Tables 3-7 and 3-8). As the sensitivity analyses indicated, the nomogram values for terrestrial invertebrates had a significant influence on estimated acute and chronic exposure.
- TIM/MCnest did not include a proximity analysis for each crop class as was done in the Kirtland's warbler breeding area model. The former essentially assumed that warblers either foraged directly in the treated area or in the adjacent edge habitat. As is evident from the proximity analysis described in Section 3.1, many Kirtland's warbler habitats are a kilometer or more away from potentially treated areas depending on the crop class. As a result, exposure of dietary items via spray drift is considerably reduced.

There are many other differences between TIM/MCnest and the Kirtland's warbler breeding area model (e.g., time step, use patterns, dissipation rates). In general, TIM/MCnest relied less on MAL-specific and species-specific foraging behavior information than did the Kirtland's warbler breeding area model.

Perhaps not surprisingly, given the conservative assumption in the exposure portion of TIM/MCnest, the models predicted significant mortality (90 to 100% assuming high sensitivity, 15 to 35% assuming median sensitivity) and large impacts on reproductive fecundity for Kirtland's warblers annually for the pasture and other crops use patterns, (Appendix 4-7 in EPA, 2016). These effects are predicted to occur annually. Such significant effects on a listed species would have serious consequences on abundance. In fact, despite decades of widespread use of malathion (and other organophosphate insecticides), the abundance of the Kirtland's warbler has increased from 167 singing males in 1974 to 2090 singing males in 2012 (FWS, 2012). In 2012, the US Fish and Wildlife Service proposed to downlist the Kirtland's warbler from endangered to threatened (http://www.fws.gov/midwest/endangered/birds/Kirtland/pdf/kiwa5YrRevAug2012.pdf). There have also been discussions of delisting the species altogether (Scott Hicks, US Fish and Wildlife Service, personal communication to Roger Breton, Intrinsik Environmental Sciences, on May 31, 2016). Clearly, the remarkable recovery of the Kirtland's warbler in recent decades is at odds with the predictions of the TIM/MCnest models.

In the following sections, we present the results from the breeding area and migration models for the Kirtland's warbler and compare them to the predictions of TIM/MCnest.

6.1 Breeding Area Model

Unlike the significant acute and chronic risk predictions from TIM/MCnest, the Kirtland's warbler breeding area model predicted negligible acute and chronic risk (Table 6-1). The LC10 for the most sensitive terrestrial invertebrate species was frequently exceeded for most use patterns. The latter indicates potential MAL risk to sensitive terrestrial invertebrates in Kirtland's warbler breeding areas. Thus, a refined risk assessment is required to determine if MAL could affect overall prey abundance in Kirtland's warbler habitats.

Table 6-1 Acute and chronic risk estimates for Kirtland's warblers and invertebrate prey potentially exposed to MAL during the breeding season

Use Pattern	*Acute Risk – Single Species LD50*	*Chronic Risk – Birds >NOEL (%)*	*Invertebrate Risk >LC10 (%)*
Alfalfa – 1.25 lb/A 2X @ 14-d interval, aerial	0	0	62.5
Alfalfa – 1.25 lb/A 2X @ 14-d interval, ground	0	0	14.1
Apple – 1.25 lb/A 2X @ 7-d interval, aerial	0	0	11.4
Apple – 1.25 lb/A 2X @ 7-d interval, airblast	0	0	3.67

Table 6-1 Acute and chronic risk estimates for Kirtland's warblers and invertebrate prey potentially exposed to MAL during the breeding season			
Use Pattern	***Acute Risk – Single Species LD50***	***Chronic Risk – Birds >NOEL (%)***	***Invertebrate Risk >LC10 (%)***
Apple – 1.25 lb/A 2X @ 7-d interval, ground	0	0	2.44
Christmas tree – 3.2 lb/A 2X @ 7-d interval, aerial	0	0.01	21.4
Christmas tree – 3.2 lb/A 2X @ 7-d interval, ground	0	0	9.45
Corn – 1 lb/A 2X @ 7-d interval, aerial	0	0	7.01
Corn – 1 lb/A 2X @ 7-d interval, ground	0	0	40.1
Dry bean – 0.61 lb/A 2X @ 7-d interval, aerial	0	0	12.7
Dry bean – 0.61 lb/A 2X @ 7-d interval, ground	0	0	1.51
Potato – 1.56 lb/A 2X @ 7-d interval, aerial	0	0	33.6
Potato – 1.56 lb/A 2X @ 7-d interval, ground	0	0	8.72
Oats – 1 lb/A 2X @ 7-d interval, aerial	0	0	25.4
Oats – 1 lb/A 2X @ 7-d interval, ground	0	0	4.3

6.2 Migration Model

The migration model for Kirtland's warblers indicates that acute mortality is not expected even if the species is assumed to be sensitive (Table 6-2).

Table 6-2 Acute risk estimates for Kirtland's warblers potentially exposed to MAL during spring and fall migration	
Season	***Mortality (%)***
Spring Migration	0
Fall Migration	0

6.3 Discussion

The results from the breeding area and migration models indicate that MAL poses little direct risk to Kirtland's warblers (Tables 6-1 and 6-2). These results are not surprising given the relatively low toxicity of malathion to avian species and that abundance of Kirtland's warblers has dramatically increased in recent decades despite widespread usage of malathion. Further, decades of intense observation of Kirtland's warblers have conclusively demonstrated that contaminants were never the issue – rather it was loss of young jack pine habitat because of fire suppression and nest parasitism by cowbirds that were the primary drivers adversely impacting warbler abundance (Walkinshaw, 1983; FWS, 2012; Bocetti et al., 2014). With the creation of large tracts of managed jack pine habitat and active cowbird removal, numbers of Kirtland's warblers improved, dramatically so (FWS, 2012; Bocetti et al., 2014). The significant predictions of acute and chronic risk of MAL to breeding Kirtland's warblers from EPA do not make sense in light of the recovery of the dramatic recovery of the Kirtland's warbler in recent decades.

As described in Sections 3.3 and 4.3, sensitivity analyses have been undertaken for the breeding area and migration models. The sensitivity analyses were useful in determining which input variables had an important influence on acute and/or chronic risk during the breeding season (e.g., use pattern, nomogram for terrestrial invertebrates, model time step, territory size, nest location within breeding territories) and migration (i.e., probability of foraging in orchards during extended stopovers). Much of the information used to parameterize the critical input variables in the models was based on decades of observation of Kirtland's warblers (e.g., nest locations, territory size, probability of foraging in orchards during stopovers) or extensive MAL-specific field studies (e.g., nomogram for terrestrial invertebrates). This information was, for the most part, not considered in the TIM/MCnest analyses for Kirtland's warblers exposed to MAL.

As with any assessment, refined or otherwise, there are sources of uncertainty in this refined risk assessment for Kirtland's warblers. Some key examples include:

- The breeding area and migration models considered exposure of Kirtland's warblers to MAL via ingestion of food only. As discussed in Section 2.4, dermal contact, drinking water, and inhalation are unlikely to be important exposure routes for Kirtland's warblers.

- When there was uncertainty, key sources were quantified and incorporated in the exposure analyses (e.g., proximity of breeding territories to treated areas, territory size, nest location in breeding territories, free metabolic rate, initial dietary residue levels following application). Thus, these sources of uncertainty have been explicitly accounted for in the risk estimates described herein. Other sources of uncertainty, however, could not be fully accounted for in the breeding area and migration models, generally because data were too scarce to reliably parameterize distributions. For example, acute dose-response curves and chronic effects metrics were unavailable for Kirtland's warblers. The general approach for input variables for which values were uncertain was to use conservative point estimates (e.g., upper bounds for proportions of orchard crops treated with MAL in the migration model, assuming that Kirtland's warblers can forage in orchards during migration even though there have been no observations of warblers in orchards in over 100 years) or rely on surrogate approaches (e.g., assume most sensitive dose-response curve for acute effects metric).

The evidence from field studies that used application rates similar to or higher than the range modeled herein indicates that MAL poses little risk to birds that forage in treated areas (Giles, 1970 [MRID 00058820]; Hill et al., 1971; McLean et al., 1975; Norelius and Lockwood, 1999; Parsons and Davis, 1971; McEwen and Ells, 1975). During the breeding season, Kirtland's warblers would not forage in treated areas and only rarely during migration. Thus, it would appear that available field studies support the negligible risk predictions from the breeding area and migration models for poses to Kirtland's warblers.

7.0 CONCLUSIONS

Probabilistic, species-specific exposure models were developed to assess risks of MAL to Kirtland's warblers during the breeding season and during spring and fall migrations. The models are highly species-specific with regard to the behavior of Kirtland's warblers. Ten thousand birds are simulated in each model. The migration model simulates birds during the course of their 13- to 23-day migrations and the breeding area model simulates bird for a 60-day period following malathion application in proximity to their breeding habitats. Chemical inputs were conservative, including assumptions of maximum applications rates, 100% crop treatment in the breeding area model, and use of the most sensitive acute dose-response curve and chronic NOEL values for effects.

Using realistic and species-specific breeding area and migration models and inputs resulted in predictions of very low acute and chronic risk of MAL to Kirtland's warblers. Our refined avian assessments deliberately erred on the side of conservatism. These results clearly indicate that the labeled use of malathion poses little risk to Kirtland's warblers.

8.0 REFERENCES

Aird, P. 1989. The dispersal of the Kirtland's warbler: Myths and reality. *In:* Ennis, K.R. (ed.), At the Crossroads – Extinction or Survival, Proceedings, Kirtland's Warbler Symposium, February 9-11, 1989, Lansing, MI. US Department of Agriculture, Forest Service, Huron-Manistee National Forests, Cadillac, MI, pp. 32-37.

Anich, N.M., J.A. Trick, K.M. Greveles and J.L. Goyette. 2011. Characteristics of a red pine plantation occupied by Kirtland's warblers in Wisconsin. Wilson Journal of Ornithology 123:199-205.

Atkins, E.L., E.A. Greywood and R.L. Macdonald. 1975. Toxicity of pesticides and other agricultural chemical to honey bees. Laboratory studies, University of California Division of Agricultural Science Leaflet 2287.

Baehr, C.H. and C. Habig. 2001. Statistical evaluation of UTAB Database for use in terrestrial nontarget organism probabilistic risk assessments. *In*: Greenberg, B.M., R.N. Hull, M.H. Roberts, Jr., and R.W. Gensemer (eds.), Environmental Toxicology and Risk Assessment: Science, Policy and Standardization – Implications for Environmental Decision. American Standards for Testing Materials (ASTM), West Conshohocken, PA, pp. 96-112.

Baird, S.F. 1872. Review of American birds in the museum of the Smithsonian Institute: Part 1. Smithsonian Miscellaneous Collections 12:206-207.

Barber, I., M. Ebeling, P. Edwards, M. Riffel, J. Schabacker, K. Welter, J. Pascual and C. Wolf. 2005. Review on Initial Residue Levels of Pesticides in Arthropods Sampled in Field Studies. Unpublished study prepared by CropLife America. Report No. 3151957. Washington, DC, for Cheminova A/S, Lemvig, Denmark. [MRID 47841001].

Beavers, J.B., D. Haberlein, L.R. Mitchell and M. Jaber. 1995. Malathion: A One-Generation Reproduction Study with the Northern Bobwhite (*Colinus virginianus*). Unpublished study performed by Wildlife International Ltd, Easton, MD. Study No. 232-112A, for FMC A/S, Lemvig, Denmark. CHA Doc. No. 103 FYF. [MRID 43501501].

Berger, A.J. and B.E. Radabaugh. 1968. Returns of Kirtland's warblers to the breeding grounds. Bird-Banding 39:161-186.

Best, L.B. 1977. Nestling biology of the field sparrow. Auk 94:308-319.

Best, L.B. and J.P. Gionfriddo. 1994. House sparrow preferential consumption of carriers used for pesticide granules. Environmental Toxicology and Chemistry 13:919-925.

Blumhorst, M.R. 1990. Aerobic Soil Metabolism Study of Malathion. Unpublished study performed by EPL Bio-Analytical Services, Harristown, IL, EPL Bio-Analytical Services Inc. Study No. 135-004, for American Cyanamid Company and FMC A/S. CHA Doc. No. 45 FYF. [MRID 41721701].

Blumhorst, M.R. 1991. Aerobic Soil Metabolism Study of Malathion. Unpublished study performed by EPL Bio-Analytical Services, Harristown, IL. EPL Bio-Analytical Services Inc, Study No. 135-003, for American Cyanamid Company CHA Doc. No. 59 FYF. [MRID 42271601].

Bocetti, C.I. 1994. Density, demography, and mating success of Kirtland's warbler in managed and natural habitats. PhD Dissertation, Ohio State University, Columbus, OH. 127 pp.

Bocetti, C.I., D.M. Donner and H.F. Mayfield. 2014. Kirtland's warbler (*Setophaga kirtlandii*). *In:* Poole, A. (ed.), The Birds of North America Online, Cornell Lab of Ornithology, Ithaca, NY. http://bna.birds.cornell.edu/bna/species/019/articles/introduction.

Breton, R., G. Manning, Y. Kara, S. Rodney and K. Wooding. 2014a. Cheminova's Ecotoxicological Study Evaluation Criteria, Study Evaluations and Proposed Screening-level Effects Metrics for the Registration Review of Malathion. Unpublished report prepared by Intrinsik Environmental Sciences, Inc., Ottawa, ON, Project No. 60320, for Cheminova, Inc., Arlington, VA. Final report dated March 4, 2014. [MRID 49333901].

Breton, R, Y. Clemow, G. Manning, D.R.J. Moore and C. Greer. 2014b. Cheminova's Comments on EPA's Preliminary Problem Formulation for the Registration Review of Malathion. Unpublished report prepared by Intrinsik Environmental Sciences, Inc., Ottawa, ON, Project No. 60320, for Cheminova, Inc., Arlington, VA. Final report dated May 30, 2014. [MRID 49400601].

Brewer, L.W., H.L. McQuillen Jr., M.A. Mayes, J.M. Stafford and S.L. Tank. 2003. Chloropyrifos residue levels in avian food items following applications of a commercial EC formulation to alfalfa and citrus. Pest Management Science 59:1179-1190.

Cannon, J.M., E. Murrill and V. Reddy. 1993. Meat and Egg Metabolism Study with 14C-Malathion in White Leghorn Chickens. Unpublished study performed by Bio-Life Associates, Ltd., Neillsville, Wisconsin and Midwest Research Institute, Kansas City, MO, BLAL Study No. 89 EM 12; MRI Project No. 9660-F, for FMC A/S. CHA Doc No. 67 FYF. [MRID 42715401].

Challinor, D., Jr. 1962. Recent sight record of Kirtland's warbler in the Bahamas. Wilson Bulletin 74:290.

Cheminova A/S. 1988. Product Chemistry - Fyfanon Technical-EPA Registration Number 4787-5. Series 63 – Physical and Chemical Characteristics. (Updated Version of Accession Numbers 245599 and 245600 submitted May, 1981.). Unpublished updated version of MRID 00079251 and 00079318, Study No. MVF/00.01.89-Fyfanon,Cheminova A/S. Lemvig, Denmark. [MRID 40966603].

Chesser, R.T., R.C. Banks, F.K. Barker, C. Cicero, J.L. Dunn, A.W. Kratter, I.K. Lovette, P.C. Rasmussen, J.V. Remsen, J.D. Rising, D.F. Stotz and K. Winker. 2011. Fifty-second supplement to the American Ornithologists' Union Check-List of North American Birds. Auk 128:600-613.

CLA (Crop Life America, GeoStac). 2015. County Boundaries. Available online: http://geostac.tamu.edu/summary

DeLoria-Sheffield, C.M., K.F. Millenbah, C.I. Bocetti, P.W. Sykes and C.B. Kepler. 2001. Kirtland's warbler diet as determined through fecal analysis. Wilson Bulletin 113:384-387.

Donner, D.M., J.R. Probst and C.A. Ribic. 2008. Influence of habitat amount, arrangement, and use on population trend estimates of male Kirtland's warblers. Landscape Ecology 23:467-480.

Dunn, J.L. and K.L. Garrett. 1997. A Field Guide to Warblers of North America. Houghton Mifflin Company, New York, NY.

Ebke, K.P. 2002. Evaluation of direct and indirect effects of a 440 g/L EW formulation of malathion on aquatic organisms in outdoor ponds. Unpublished study performed by Covance Laboratories GmbH, Münster, Germany, Report No. 1754-0676-019, for FMC A/S. CHA Doc No. 379 FYF. [MRID 46525901].

ECOFRAM. 1999. Terrestrial Draft Report. United States Environmental Protection Agency, Washington, DC. http://www.epa.gov/oppefed1/ecorisk/terrreport.pdf.

EPA (US Environmental Protection Agency). 1993. Wildlife Exposure Factors Handbook. Volumes I and II. Office of Research and Development. Washington, DC. EPA EPA/600/R-93/187a, EPA/600/R-93/187b.

EPA (US Environmental Protection Agency). 1998. Guidelines for Ecological Risk Assessment. Office of Research and Development, Washington, DC. EPA/630/R- 95/002F.

EPA (US Environmental Protection Agency). 2005. Re-Registration Eligibility Science Chapter for Carbofuran. Environmental fate and effects chapter. Environmental risk assessment and human drinking water exposure assessment, June 3, 2005. Office of Pesticide Programs, Washington, DC.

EPA (US Environmental Protection Agency). 2007. Risks of Malathion Use to Federally Listed California Red-legged frog (*Rana aurora draytonii*). Pesticide Effects Determination. Office of Pesticide Programs, Washington, DC. October 19, 2007.

EPA (US Environmental Protection Agency). 2009a. Reregistration Eligibility Decision (RED) for Malathion. Office of Pesticide Programs, Washington, DC.

EPA (US Environmental Protection Agency). 2009b. User's Guide and Technical Documentation KABAM version 1.0 (Kow (based) Aquatic BioAccumulation Model). Office of Pesticide Programs, Washington, DC. https://www.epa.gov/sites/production/files/2015-07/documents/kabam_v1_0_users_guide.pdf.

EPA (US Environmental Protection Agency). 2010a. Screening Tool for Inhalation Risk (STIR) Version 1.0. Office of Pesticide Programs, Washington, DC.

EPA (US Environmental Protection Agency). 2010b. Screening Imbibition Program (SIP). SIP Version 1.0 User's Guide for Pesticide Exposure of Birds and Mammals through Drinking Water. Accessed online: http://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/sip-version-10-users-guide-pesticide-exposure-birds. Office of Pesticide Programs, Washington, DC.

EPA (US Environmental Protection Agency). 2010c. Risks of Malathion Use to the Federally Threatened Delta Smelt (*Hypomesus trasnpacificus*) and California Tiger Salamander (*Ambystoma californiese*), Central California Distinct Population Segment, and the Federally Endangered California Tiger Salamander, Santa Barbara County and Sonoma County Distinct Population Segments. Office of Pesticide Programs, Washington, DC. https://www3.epa.gov/pesticides/endanger/litstatus/effects/redleg-frog/2010/malathion/assessment2.pdf

EPA (US Environmental Protection Agency). 2016. Biological Evaluation Chapters for Malathion. https://www.epa.gov/endangered-species/biological-evaluation-chapters-malathion#chapter%202. Office of Pesticide Programs, Washington, DC. Last updated April 22, 2016.

Ewert, D.N., J.M. Wunderle, C.W. Eberly, P.W. Huber and E. Carey. 2009. The Kirtland's warbler: Interagency and international cooperation works. Endangered Species Update 26:31-38.

Fautin, R.W. 1941. Development of nestling yellow-headed blackbirds. Auk 58:215-232.

Fletcher, J.S., J.E. Nellessen and T.E. Pfleeger. 1994. Literature review and evaluation of the EPA food-chain (Kenaga) nomogram, an instrument for estimating pesticide residues on plants. Environmental Toxicology and Chemistry 13:1383-1391.

Forsyth, D.J. and N.D. Westcott. 1994. Carbofuran residues in grasshoppers and vegetation from aerially sprayed prairie pastures: Potential effects on wildlife. Environmental Toxicology and Chemistry 13(2):299-306.

Fussman, J.L. 1997. Foraging ecology of Kirtland's warblers in managed and natural breeding habitat. MSc Thesis, Ohio State University, Columbus, OH. 73 pp.

FWS (Fish and Wildlife Service). 1976 (Revised 1985). Kirtland's Warbler Recovery Plan. US Fish and Wildlife Service, Twin Cities, MN.

FWS (Fish and Wildlife Service). 2012. Kirtland's Warbler (*Dendroica kirtlandii*) 5-Year Review: Summary and Evaluation. US Fish and Wildlife Service, East Lansing Field Office, East Lansing, MI.

Gallagher, S.P., J. Grimes and J.B. Beavers. 2002a. Malaoxon: An Acute Oral Toxicity Study with the Northern Bobwhite. Unpublished study performed by Wildlife International, Ltd., Easton, MD, Project No. 232-120, for Cheminova A/S CHA Doc. No. 374 FYF. [MRID 48153104].

Gallagher, S.P., J. Grimes, J.B. Beavers and K.H. Martin. 2002b. Malaoxon: A Dietary LC50 Study with the Northern Bobwhite. Unpublished study performed by Wildlife International, Ltd., Easton, MD, Project No. 232-119A, for Cheminova A/S. CHA Doc. No. 383 FYF. [MRID 48153105].

Gallagher, S.P., J. Grimes, J.B. Beavers and K.H. Martin. 2003. Fyfanon Technical: A Dietary LC50 Study with the Northern Bobwhite. Unpublished study performed by Wildlife International, Ltd. Easton, MD, Project No. 232-121, for Cheminova A/S CHA Doc. No. 434 FYF. [MRID 48153106].

Giles, R.H. Jr. 1970. The ecology of a small forested watershed treated with the insecticide malathion: S35. Wildlife Monographs 24:3-81. [MRID 00058820].

Goodman, S.M. 1982. Age and sexual morphological variation in the Kirthland's warbler (*Dendroica kirtlandii*). Jack-Pine Warbler 60:144-147.

Habig, C. 2011. Residues of Malathion and Malaoxon on Potential Avian and Mammalian Feed Items. Unpublished study performed by Exponent, Inc., Washington, DC. Exponent Project No. WD00255.000.H0T0-2011-001, for Cheminova A/S. [MRID 48409301].

Hanebeck, I. and T. Staedtler. 2011. Residues of Malathion and Malaoxon in Arthropods and Ground Vegetation after Spray Application of an EW Formulation Containing 440 g Malathion/L in an Alfalfa Field in Spain – Magnitude of Residues and Time Course of Residue Decline. Unpublished study performed by RIFCON GmbH, Heidelberg, Germany, GLP Study No. 127, RIFCON GmbH Report No. R10327, for Cheminova A/S. CHA Doc. No. 1051 FYF. [MRID 49086411].

Haney, J.C., D.S. Lee and M. Walsh-McGehee. 1998. A quantitative analysis of winter distribution and habitats of Kirtland's warbler in the Bahamas. Condor 100:201-217.

Hiler, T. 2012. Aerobic Soil Metabolism of [^{14}C]Malaoxon in Four Soils. Unpublished study performed by PTRL West, Inc. Hercules, CA, Project No. 2144W, for Cheminova A/S. [MRID 48903601].

Hiler, T. and L. Mannella. 2012. Aerobic Aquatic Metabolism of [14C] Malathion Unpublished study performed by PTRL West, Inc., Hercules, CA, Project No. 2143W, for FMC A/S. [MRID 48906401].

Hill, E.F., D.A. Eliason and J.W. Kilpatrick. 1971. Effects of ultra-low volume applications of malathion in Hale County, Texas. Journal of Medical Entomology 8(2):173-179.

Hoerger, F.D. and E.E. Kenaga. 1972. Pesticide Residues on Plants: Correlation of Representative Data as a Basis for Estimation of their Magnitude in the Environment. *In*: Coulston, F. and F. Korte (eds.), Environmental Quality and Safety – Global Aspects of Chemistry, Toxicology and Technology as Applied to the Environment, Academic Press, NY, NY. pp. 9-23.

Huber, P.W., K. Kintigh and S. Sjogren. 2013. Kirtland's Warbler Habitat Update. Unpublished Report, Huron-Manistee National Forests. 9 pp.

Hubbard, P.M. and J.B. Beavers. 2012a. Malathion: An Acute Oral Toxicity Study with the Mallard. Unpublished study performed by Wildlife International, Ltd. Easton, MA, Project No. 232-157, for Cheminova A/S. 1090 FYF. [MRID 48963307].

Hubbard, P.M. and J.B. Beavers. 2012b. Malaoxon: An Acute Oral Toxicity Study with the Mallard. Unpublished study performed by Wildlife International, Ltd. Easton, MD, Project No. 232-154, for Cheminova A/S. CHA Doc No. 1089 FYF. [MRID 48963306].

Hubbard, P.M. and J.B. Beavers. 2012c. Malathion: An Acute Oral Toxicity Study with the Ring-Necked Pheasant. Unpublished study performed by Wildlife International, Ltd. Easton, MD, Project No. 232-158, for Cheminova A/S. 1091 FYF. [MRID 48963305].

Hubbard, P.M., K.H. Martin and J.B. Beavers. 2012a. Malathion: A Dietary LC50 Study with the Ring-necked Pheasant. Unpublished study performed by Wildlife International, Ltd. Easton, MD, Project No. 232-156, for Cheminova A/S. [MRID 48963301].

Hubbard, P.M., K.H. Martin and J.B. Beavers. 2012b. Malaoxon: A Dietary LC50 Study with the Ring-Necked Pheasant. Unpublished study performed by Wildlife International, Ltd., Easton, MD, Project No. 232-162, for Cheminova A/S. 1250 FYF. [MRID 48963302].

Hubbard, P.M., K.H. Martin and J.B. Beavers. 2012c. Malathion: A Dietary LC50 Study with the Mallard. Unpublished study performed by Wildlife International, Ltd. Easton, MD, Project No. 232-155, for Cheminova A/S. 1241 FYF. [MRID 48963303].

Hubbard, P.M., K.H. Martin and J.B. Beavers. 2012d. Malaoxon: A Dietary LC50 Study with the Mallard. Unpublished study performed by Wildlife International, Ltd., Easton, MD, Project No. 232-153, for Cheminova A/S. CHA Doc No. 1240 FYF. [MRID 48963304].

Hubbard, P.M., J.B. Beavers and K.H. Martin. 2012e. Malaoxon: An Acute Oral Toxicity Study with the Ring-Necked Pheasant. Unpublished study performed by Wildlife International, Ltd., Easton, MD, Project No. 232-163, for Cheminova A/S. [MRID 49024601].

Kashian, D.M., B.V. Barnes and W.S. Walker. 2003. Landscape ecosystems of Northern Lower Michigan and the occurrence and management of the Kirtland's warbler. Forest Science 49:140-159.

Kenaga, E.E. 1973. Factors to be considered in the evaluation of the toxicity of pesticides to birds in the environment. Environmental Quality and Safety 2:166-181.

Kessel, B. 1957. A study of breeding biology of the European starling (*Sturnus vulgaris* L.) in North America. American Midland Naturalist 58:257-331.

Kluijver, H.N. 1950. Daily routines of the great tit, *Parus m. major* L. Ardea 38:99-135.

Knäbe, S. 2003. A field trial assessing the impact of multiple applications of CHE 3110 on the non-target arthropod fauna of an alfalfa (*Medicago sativa*) crop (Italy). Unpublished study performed by GAB Biotechnologie Gmbh, GAB Project No. 20021159/11-FNTO, for Cheminova A/S. CHA Doc. No. 438 FYF. [MRID 49086408].

Knäbe, S. 2004. Residues of Malathion and Malaoxon in Different Feed Sources for Wild Birds After Application of CHA 3110 (Germany 2004). Unpublished study performed by GAB Biotechnologie GmbH & GAB Analytik GmbH, Niefern-Öschelbronn, Germany, Study code 20041219/G1-FNTO, for Cheminova A/S. CHA Doc No. 493 FYF. [MRID 46525902].

Knoch, E. 2001a. Degradability and Fate of Malathion in the Aquatic Environment (Water/Sediment System). Unpublished study performed by Institut Fresenius Chemische und Biologische Laboratorien GmbH, Herten, Germany, Study No.IF-100/30746-00, for Cheminova A/S. CHA Doc. No. 337 FYF. [MRID 46769502].

Knoch, E. 2001b. Malathion: Aerobic Soil Metabolism. Unpublished study performed by Institut Fresenius Chemische und Biologische Laboratorien GmbH, Herten, Germany, Study No.IF-100/30745-00, for Cheminova A/S. CHA Doc. No. 336 FYF. [MRID 46769501].

Lee, D.S., M. Walsh-McGhee and J.C. Haney. 1997. History, biology and re-evaluation of the Kirtland's warbler habitat in the Bahamas. Bahamas Journal of Science 4:19-29.

Mangels, G. 1987. Malathion (CL 6,601): The Determination of the n-Octanol/Water Partition Coefficient. Unpublished study performed by American Cyanamid Company. Laboratory Report No. D-M 24-39, for BASF Corporation. CHA Doc. No. 26 FYF. [MRID 40944108].

Mayfield, H. 1953. A census of the Kirtland's warbler. Auk 70:17-20.

Mayfield, H. 1960. The Kirtland's Warbler. Cranbrook Institute of Science, Bloomfield Hills, MI. 242 pp.

Mayfield, H.F. 1972. Winter habitat of Kirtland's warbler. Wilson Bulletin 84:347-349.

Mayfield, H.F. 1992. Kirtland's warbler (*Dendroica kirtlandii*). *In:* Poole, A. (ed.), The Birds of North America, Academy of Natural Sciences, Philadelphia, PA.

Mayfield, H.F. 1996. Kirtland's warblers in winter. Birding 28:34-39.

McEwen, L.C. and J.O. Ells. 1975. Field Ecology Investigations of the Effects of Selected Pesticides on Wildlife Populations. Unpublished study prepared by Wildlife Research Unit, Wildlife Research Center, Denver, CO, Technical Report No. 289, for Grassland Biome's US International Biological Program.

McLean, R.G., J.T. Spillane and J. W. Miles. 1975. A prospective study of the effects of ultralow volume (UVL) aerial application of malathion on epidemic Plasmodium Falciparum Malaria III ecological aspects. American Journal of Tropical Medicine and Hygiene 24(2):193-198.

Moore, D.R.J., R.S. Teed, C. Greer, K.R. Solomon and J.P. Geisy. 2014a. Refined avian risk assessment for flowable and granular formulations of chlorpyrifos in North America. Reviews of Environmental Contamination and Toxicology 231:163-218.

Moore, D.R.J., Y. Clemow, S. Rodney and R. Breton. 2014b. Avian and Mammalian Dietary Items: Half-Lives and Residue Unit Doses for Malathion. Unpublished report prepared by Intrinsik Environmental Sciences Inc., Ottawa, ON, Project No. 60320, for Cheminova Inc, Arlington, VA. [MRID 49389301].

Müther, J. 2003. A field study to evaluate the effects of CHA 3110 on the non-target arthropod fauna in an apple orchard in France. Unpublished study performed by GAB Biotechnologie

Gmbh, Lab project No. 20021159/F1-FNTO, for Cheminova A/S. CHA Doc. No. 437 FYF. [MRID 49086409].

Nagy, K.A., I.A. Girard and T.K. Brown. 1999. Energetics of free-ranging mammals, reptiles and birds. Annual Review of Nutrition 19:247-277.

Namba, T. 1971. Cholinesterase inhibition by organophospourus compounds and its clinical effects. Bulletin of the World Health Organization 44:289-307.

Nixon, W. 1995. Column Leaching of [^{14}C] Malathion in Four Soil Types Following Aerobic Aging. Unpublished study performed by PTRL East, Inc. Richmond, KY, Project No. 951, Report No. 1842, for Cheminova A/S. [MRID 43868601].

Norelius, E.E. and J.A. Lockwood. 1999. The effects of reduces agent-area insecticide treatments for rangeland grasshopper (Orthoptera: Acrididae) control on bird densities. Archives of Environmental Contamination and Toxicolicology 37:519-528.

Orr, C.D. 1975. 1974 breeding success of the Kirtland's warbler. Jack Pine Warbler 53:59-66.

Parsons, J.K. and B.D. Davis. 1971. The Effects on Quail, Migratory Birds and Non-Game Birds from Application of Malathion and Other Insecticides. Texas Parks and Wildlife Dept. Study conducted from 1964 to 1968.

Pedersen, C. and D. Fletcher. 1993. AC 6601 Technical: Toxicity and Reproduction Study in Mallard Ducks. Unpublished study performed by Bio-Life Associates, Ltd., Neillsville, WI, Project No. 90 DR 39, for Cheminova Agro A/S; CHA Doc. No. 69 FYF. [MRID 42782101].

Petrucha, M.E., P.W. Sykes, Jr., P.W. Huber and W.W. Duncan. 2013. Spring and fall migrations of Kirtland's warblers (*Setophaga kirtlandii*). North American Birds 66:382-427.

Pinkowski, B.C. 1978. Feeding of nestling and fledgling eastern bluebirds. Wilson Bulletin 90:84-98.

Powell, G.V.N. 1984. Reproduction by an altricial songbird, the red-winged blackbird, in fields treated with the organophosphate insecticide fenthion. Journal of Applied Ecology 21(1):83-95.

Probst, J.R. 1988. Kirtland's warbler breeding biology and habitat management. *In:* Hoekstra, T.W. and J. Capp (eds.), Integrating Forest Management for Wildlife and Fish, General Technical Report No. NC-122, US Department of Agriculture, Forest Service, North Central Forest Experiment Station, St. Paul, MN. pp. 28-35.

Probst, J.R. and J. Weinrich. 1993. Relating Kirtland's warbler population to changing landscape composition and structure. Landscape Ecology 8:257-271.

Probst, J.R., D.M. Donner, C.I. Bocetti and S. Sjogren. 2003. Population increase in Kirtland's warbler and summer range expansion to Wisconsin and Michigan's Upper Peninsula, USA. Oryx 37:365-373.

Radabaugh, B.E. 1974. Kirtland's warbler and its Bahama wintering grounds. Wilson Bulletin 86:374-383.

Rockwell, S. 2010. 2010 Final Report: Small Grant for KIWA Research. Smithsonian Migratory Bird Center. Unpublished report.

Rockwell, S.M. 2013. Carry-over effects from the non-breeding season influence spring arrival dates, reproductive success, and survival in an endangered migratory bird, the Kirtland's warbler (*Setophaga kirtlandii*). PhD dissertation, University of Maryland, College Park, MD.

Rodgers, H. 2002. Malathion Technical – Acute Oral Toxicity (LD50) to the Bobwhite Quail (*Colinus virginianus*). Unpublished study performed by Huntington Life Sciences, Ltd., Cambridgeshire, England, Project ID CHV 075, for Cheminova A/S, Lemvig, Denmark. CHA Doc. No. 338 FYF. [MRID 48153114].

Ryel, L.A. 1979. On the population dynamics of Kirtland's warbler. Jack-Pine Warbler 59:76-91.

Saxena, A.M. 1988. Aerobic and Aerobic/Anaerobic Soil Metabolism of ^{14}C-Malathion on Loamy Sand Soil. Unpublished study performed by Hazleton Laboratories America, Inc. Madison, WI, Lab Project No. HLA 6123-153, for American Cyanamid Company. CHA Doc. No. 061 FYF. [MRID 47834301].

Sindermann, A.B. and J.R. Porch. 2013a. Fyfanon Technical: An Acute Contact Toxicity Study with the Honey Bee. Unpublished study performed by Wildlife International Ltd., Easton, MD, Study No. 232P-113, for Cheminova A/S. Final report dated December 2, 2013. [MRID 49270301].

Sindermann, A.B. and J.R. Porch. 2013b. Fyfanon Technical: An Acute Oral Toxicity Study with the Honey Bee. Unpublished study performed by Wildlife International Ltd., Easton, MD, Study No. 232P-113, for Cheminova A/S. Final report dated December 2, 2013. [MRID 49270302].

Sindermann, A.B., J.R. Porch, H.O. Krueger and K.H. Martin. 2013. Malathion 57%: A Test to Determine the Effects on Vegetative Vigor of Ten Species of Plants. Unpublished study performed by Wildlife International Ltd., Easton, MD, Study No. 232P-102, for Cheminova A/S. Final report dated February 27, 2013. [MRID 49076002].

Staedtler, T., K. Henkes and I. Hanebeck. 2011. Residues of Malathion and Malaoxon on Arthropods and Ground Vegetation after Spray Application of an EW Formulation Containing 440 g Malathion/L in an Oilseed Rape Field in Germany – Magnitude of Residues and Time Course of Residue Decline. Unpublished study performed by RIFCON GmbH, Heidelberg, Germany, for Cheminova A/S. CHA Doc. No. 1052 FYF, GLP Study No. 132, RIFCON GmbH Report No. R11093. [MRID 49086410].

Stafford, J. 2011a. Malathion: Acute Oral Toxicity Test (LD50) with the Canary (*Serinus canaria*). Unpublished study performed by Smithers Viscient, Snow Camp, NC. Study No. 11704.4101, for Cheminova A/S. [MRID 48571805].

Stafford, J. 2011b. Malaoxon: Acute Oral Toxicity Test (LD50) with the Canary (*Serinus canaria*). Unpublished study performed by Smithers Viscient, Snow Camp, NC. Study No. 11704.4102, for Cheminova A/S. [MRID 48571806].

Stevenson, J.H. 1968. Laboratory studies on the acute contact and oral toxicities of insecticides to honeybees. Annals of Applied Biology 61:467-474. [MRID 05004151].

Stevenson, H.M. and B.H. Anderson. 1994. The birdlife of Florida. University Press of Florida, Gainesville, FL.

Stromborg, K.L., W.N. Beyer and E. Kolbe. 1982. Diazinion residues in insects from sprayed tobacco. Chemistry and Ecology 1:93-97.

Stromborg, K.L., L.C. McEwen and T. Lamont. 1984. Organophosphate residues in grasshoppers from sprayed rangelands. Chemistry and Ecology 2:39-45.

Suter II, G.W., L.W. Barnthouse, S.M. Bartell, T. Mill, D. Mackay and S. Paterson. 1993. Ecological Risk Assessment. Lewis Publishers, Boca Raton, FL.

Sykes, P.W. and M.H. Clench. 1998. Winter habitat of Kirtland's warbler: An endangered Nearctic/neotropical migrant. Wilson Bulletin 110:244-261.

Sykes, P.W., C.B. Kepler, D.A. Jett and M.E. DeCapita. 1989. Kirtland's warblers on the nesting grounds during the post-breeding period. Wilson Bulletin 101:545-558.

Szentes, C. 2003. Acute Oral and Contact Toxicity of Fyfanon 440 g/l EW on Honeybees (*Apis mellifera*). OECD Guideline No. 314, 1998. Unpublished study performed by Ecotoxicological Laboratory, Fácánkert, Hungary, Project No. 2916/03, for Cheminova A/S. Final report dated October 27, 2003. CHA Doc No. 459 FYF. [MRID 49051205].

Torchio, P.F. 1973. Relative toxicity of insecticides to the honey bee, Alkali bee and alfalfa leafcutting bee (Hymenoptera: Apidae, Halictidae, Megachilidae). Journal of the Kansas Entomological Society 46(4):446-453.

Walkinshaw, L.H. 1983. Kirtland's warbler: The natural history of an endangered species. Cranbrook Institute of Science, Bloomfield Hills, MI.

Wootton, M. S. and T. Johnson. 1993. A confined rotational crop study with ^{14}C-malathion using turnips (*Brassica rapa*), lettuce (*Lactuca sativa*) and wheat (*Triticum aestivum*). Unpublished study performed by PTRL East, Inc., Richmond, KY. PTRL Project No. 422; PTRL Report No. 1506, for Cheminova Agro A/S. CHA Doc. No. 72 FYF. [MRID 42785501].

Wunderle, J.M., D. Currie and D.N. Ewert. 2007. The potential role of hurricanes in the creation and maintenance of Kirtland's warbler winter habitat in the Bahamian Archipelago. *In*: Proceedings of the 11th Symposium on the Natural History of the Bahamas, Gerace, Research Center, San Salvador, The Bahamas, pp. 121-129.

Wunderle, J.M., D. Currie, E.H. Helmer, D.N. Ewert, J.D. White, T.S. Ruzycki, B. Parresol and C. Kwit. 2010. Kirtland's warbler in anthropogenically disturbed early-successional habitats on Eleuthera, The Bahamas. Condor 112:123-137.

MRID 00159878

Appendix A
Malathion Use Patterns

Table A-1 Full FIFRA non-ULV use patterns[a]					
Crop	***Application Method***	***Maximum Single Application Rate (lb ai/A)***	***Maximum Number of Applications per Season***	***Maximum Application Rate per Season (lb ai/A)***	***Minimum Retreatment Interval (Days)***
Agricultural Uses					
Alfalfa	Aerial, Ground	1.25	2 per cutting (6)	7.5	14
Apples	Aerial, Ground, Airblast	1.25	2	2.5	7
Apricot	Aerial, Ground, Airblast	1.5	2	3	7
Asparagus	Aerial, Ground	1.25	2	2.5	7
Avocado	Ground, airblast	4.7	2	9.4	30
Barley	Aerial, Ground	1.25	2	2.5	7
Beets, garden	Aerial, Ground	1.25	3	3.75	7
Blueberry (high bush and low bush)	Aerial, airblast, Ground	1.25	3	3.75	5
Blueberry (high bush and low bush)[a]	Aerial, airblast, Ground	2.5	2	5	5
Broccoli, Chinese Broccoli, Broccoli rabe	Aerial, Ground	1.25	2	2.5	7
Brussels sprouts	Aerial, Ground	1.25	2	2.5	7
Cabbage	Aerial, Ground	1.25	6	7.5	7
Caneberries (blackberry, boysenberry, dewberry, gooseberry, loganberry, raspberry)	Aerial, Ground, Airblast	2	3	6	7
Cantaloupe	Aerial, Ground	1	2	2	7
Carrots	Aerial, Ground	1.25	2	2.5	7
Cauliflower	Aerial, Ground	1.25	2	2.5	7
Celery	Aerial, Ground	1.5	2	3	7
Chayote fruit	Aerial, Ground	1.75	2	3.5	7
Chayote root	Aerial, Ground	1.56	2	3.12	7
Cherries, sweet	Aerial, Ground, Airblast	1.75	4	7	3
Cherries, tart	Aerial, Ground, Airblast	1.75	4	7	3
Chestnut	Aerial, Ground. airblast	2.5	3	7.5	7
Chinese greens (Chinese cabbage)	Aerial, Ground	1.25	2	2.5	7

Table A-1 Full FIFRA non-ULV use patterns[a]

Crop	*Application Method*	*Maximum Single Application Rate (lb ai/A)*	*Maximum Number of Applications per Season*	*Maximum Application Rate per Season (lb ai/A)*	*Minimum Retreatment Interval (Days)*
Citrus Fruits (grapefruit, lemon, lime, orange, tangerine, tangelo)	Aerial, Ground, Airblast	1.5	3	4.5	30
Citrus Fruits (grapefruit, lemon, lime, orange, tangerine, tangelo)	Airblast	All states other than CA: 4.5	1	4.5	n/a
Citrus Fruits (grapefruit, lemon, lime, orange, tangerine, tangelo)	Airblast	CA only: 7.5	1	7.5	n/a
Clover	Aerial, Ground	1.25	2 per cutting (6)	7.5	14
Collards	Aerial, Ground	1	3	3	7
Corn, field	Aerial, Ground	1	2	2	7
Corn, sweet, and pop	Aerial, Ground	1	2	2	5
Cotton (non boll weevil treatment use)	Aerial, Ground	2.5	3	7.5	7
Cucumber	Aerial, Ground	1.75	2	3.5	7
Currant	Aerial, Ground	1.25	3	3.75	7
Dandelion	Aerial, Ground	1.25	2	2.5	7
Eggplant	Aerial, Ground	1.56	4	6.24	5
Eggplant, oriental	Aerial, Ground	1.56	5	7.8	5
Endive (escarole)	Aerial, Ground	1.25	2	2.5	7
Fig	Aerial, Ground	1.5	2	3	5
Fig	Aerial, Ground, Airblast	2	2	4	5
Flax	Aerial, Ground	0.5	3	1.5	7
Garlic	Aerial, Ground	1.56	3	4.68	7
Grapes, raisin, table, wine	Aerial, Ground, Airblast	1.88	2	3.76	14
Grass, forage, hay	Aerial, Ground	1.25	1 per cutting	1.25	n/a
Guava	Aerial, Ground, Airblast	1.25	13	16.25	3
Hops	Aerial, Ground	0.63	3	1.89	7
Horseradish	Aerial, Ground	1.25	3	3.75	7
Kale	Aerial, Ground	1	3	3	5
Kohlrabi	Aerial, Ground	1.25	2	2.5	7
Kumquats	Airblast	4.5	1	4.5	30
Leeks	Aerial, Ground	1.56	2	3.12	7
Lespedeza	Aerial, Ground	1.25	2 per cutting (6)	7.5	14

Table A-1 Full FIFRA non-ULV use patterns[a]

Crop	*Application Method*	*Maximum Single Application Rate (lb ai/A)*	*Maximum Number of Applications per Season*	*Maximum Application Rate per Season (lb ai/A)*	*Minimum Retreatment Interval (Days)*
Lettuce, head	Aerial, Ground	1.88	2	3.76	6
Lettuce, leaf	Aerial, Ground	1.88	2	3.76	5
Macadamia nut	Aerial, Ground, Airblast	0.94	6	5.64	7
Mango	Aerial, Ground, Airblast	0.9375	10	9.375	7
Melons (other than watermelon)	Aerial, Ground	1	2	2	7
Mint	Aerial, Ground	0.94	3	2.82	7
Mustard greens	Aerial, Ground	1	3	3	5
Nectarines	Ground, Airblast	3	3	9	7
Oats	Aerial, Ground	1	2	2	7
Okra	Aerial, Ground	1.2	5	6	7
Onions, bulb, and green	Aerial, Ground	1.56	2	3.12	7
Papaya	Aerial, Ground, Airblast	1.25	8	10	3
Parsley	Aerial, Ground	1.5	2	3	7
Parsnip	Aerial, Ground	1.25	3	3.75	7
Passion fruit	Aerial, Ground	1	8	8	7
Pasture and rangeland	Aerial, Ground	1.25	1 per cutting	1.25	7
Peaches	Aerial, Ground, Airblast	3	3	9	11
Pears	Aerial, Ground, Airblast	1.25	2	2.5	7
Peas, green, dried	Aerial, Ground	1	2	2	7
Pecans	Aerial, Ground, Airblast	2.5	2	5	7
Peppers	Aerial, Ground	1.56	2	3.12	5
Pineapple	Aerial, Ground	2	3	6	7
Potatoes	Aerial, Ground	1.56	2	3.12	7
Pumpkins	Aerial, Ground	1	2	2	7
Radish	Aerial, Ground	1	3	3	7
Rice	Aerial, Ground	1.25	2	2.5	7
Rutabagas	Aerial, Ground	1	3	3	7
Rye	Aerial, Ground	1	3	3	7
Salsify	Aerial, Ground	1.25	3	3.75	7
Shallot	Aerial, Ground	1.56	2	3.12	7
Sorghum	Aerial, Ground	1	2	2	7
Spinach	Aerial, Ground	1	2	2	7
Squash, summer	Aerial, Ground	1.75	3	5.25	7
Squash, winter	Aerial, Ground	1	3	3	7
Strawberry	Aerial, Ground	2	4	8	7

Table A-1 Full FIFRA non-ULV use patterns[a]

Crop	Application Method	Maximum Single Application Rate (lb ai/A)	Maximum Number of Applications per Season	Maximum Application Rate per Season (lb ai/A)	Minimum Retreatment Interval (Days)
Sweet potatoes	Aerial, Ground	1.56	2	3.12	7
Swiss chard	Aerial, Ground	1	2	2	7
Tomatoes, Tomatilloes	Aerial, Ground	1.56	4	6.24	5
Trefoil, birds foot	Aerial, Ground	1.25	2 per cutting (6)	7.5	14
Turnips (green)	Aerial, Ground	1.25	3	3.75	5
Turnips (root)	Aerial, Ground	1.25	3	3.75	7
Vetch	Aerial, Ground	1.25	2 per cutting (6)	7.5	14
Walnuts	Aerial, Ground, Airblast	2.5	3	7.5	7
Watercress	Aerial, Ground	1.25	5	6.25	3
Watermelons	Aerial, Ground	1.5	4	6	7
Wheat, spring and winter	Aerial, Ground	1	2	2	7
Wild Rice	Aerial, Ground	1.25	2	2.5	7
Yams	Aerial, Ground	1.56	2	3.12	7
Non-Agricultural Uses - Commercial Uses					
Agricultural, uncultivated areas	Aerial, Ground	1	1	1	n/a
Christmas tree plantations	Aerial, Ground	3.2	2	6.4	7
Non-agricultural uncultivated areas/soil	Aerial, Ground	0.6	1	0.6	n/a
Ornamental and/or shade trees	Ground	4	2	8	10
Ornamental herbaceous plants	Ground	4	2	8	10
Ornamental non-flowering plants	Ground	4	2	8	10
Ornamental woody shrubs and vines	Ground	4	2	8	10
Pine seed orchards	Ground	1.5	2	6.4	7
Refuse/solid waste containers (outdoors)	Ground (drench)	10.6	2	10.6	7
Refuse/solid waste sites (outdoors)	Ground (drench)	10.6	2	10.6	7
Wide Area - Public Health Use[b]	Aerial	0.23	–	–	–

Table A-1 Full FIFRA non-ULV use patterns[a]					
Crop	***Application Method***	***Maximum Single Application Rate (lb ai/A)***	***Maximum Number of Applications per Season***	***Maximum Application Rate per Season (lb ai/A)***	***Minimum Retreatment Interval (Days)***
Wide Area - Public Health Use[b]	Ground (non-thermal fog)	0.06	–	–	–
Non-Agricultural Uses - Homeowner/Residential Use					
Fence rows/hedge rows	Ground	10.6	4	10.6	7
Household/domestic dwellings (perimeter outdoor only)	Ground (drench)	10.6	4	10.6	7
Ornamental and/or shade trees	Spot treatment	4	2	8	10
Ornamental herbaceous plants	Spot treatment	4	2	8	7
Ornamental non-flowering plants	Spot treatment	4	2	8	7
Ornamental woody shrubs and vines	Spot treatment	4	2	8	10

[a] 24(c) Special Local Needs Label for the control of spotted wing drosophila in FL, MA, NH, and NJ.

[b] Site cannot be re-treated more than three times in any one week.

Table A-2 Full FIFRA ULV use patterns					
Crop	**Application Method**	**Maximum Single Application Rate (lb ai/A)**	**Maximum Number of Applications per Season**	**Maximum Application Rate per Season (lb ai/A)**	**Minimum Retreatment Interval (Days)**
Agricultural Uses					
Alfalfa	Aerial, Ground	0.61	2 per cutting (6)	1.22	14
Barley	Aerial, Ground	0.61	2	1.22	7
Beans, dry, snap, Lima	Aerial, Ground	0.61	2	1.22	7
Blueberry (high bush and low bush)	Aerial, Ground, Airblast	0.77	3	2.31	10
Blueberry (high bush and low bush)[a]	Aerial, Ground, Airblast	0.77	5	3.85	10
Cherries, sweet	Aerial, Ground, Airblast	1.22	4	4.88	7

Table A-2 Full FIFRA ULV use patterns

Crop	Application Method	Maximum Single Application Rate (lb ai/A)	Maximum Number of Applications per Season	Maximum Application Rate per Season (lb ai/A)	Minimum Retreatment Interval (Days)
Cherries, tart	Aerial, Ground, Airblast	1.22	6	7.32	7
Citrus Fruits (grapefruit, lemon, lime, orange, tangerine, tangelo)	Aerial, Ground, Airblast	0.175	3	0.525	7
Clover	Aerial, Ground	0.61	2 per cutting (6)	1.22	14
Corn, field	Aerial, Ground	0.61	2	1.22	7
Corn, sweet, and pop	Aerial, Ground	0.61	2	1.22	5
Cotton (non-boll weevil treatment use)[b]	Aerial, Ground	1.22	3	3.66	7
Kumquats	Aerial, Ground, Airblast	0.175	2	0.35	7
Lespedeza	Aerial, Ground	0.61	2 per cutting (2)	1.22	14
Lupine	Aerial, Ground	0.61	1	0.61	n/a
Oats	Aerial, Ground	0.61	2	1.22	7
Pasture and rangeland	Aerial, Ground	0.92	1 per cutting	0.92	7
Rice	Aerial, Ground	0.61	2	1.22	7
Rye	Aerial, Ground	0.61	1	0.61	n/a
Sorghum	Aerial, Ground	0.61	2	1.22	7
Trefoil, birdsfoot	Aerial, Ground	0.61	2 per cutting (2)	1.22	14
Vetch	Aerial, Ground	0.61	2 per cutting (2)	1.22	14
Wheat, spring and winter	Aerial, Ground	0.61	2	1.22	7
Wild Rice	Aerial, Ground	0.61	2	1.22	7
Non-Agricultural Uses					
Agricultural, uncultivated areas	Aerial, Ground	0.1875	1	0.1875	n/a
Christmas tree plantations	Aerial, Ground	0.9375	2	1.875	7
Non-Agricultural rights of way/fencerows	Aerial, Ground	0.9281	1	0.9281	n/a
Non-agricultural uncultivated areas/soil	Aerial, Ground	0.9281	1	0.9281	n/a
Pine seed orchards	Aerial, Ground	0.9375	2	1.875	7
Wide Area - Public Health Use[c]	Aerial	0.23	–	–	–
Wide Area - Public Health Use[c]	Ground (non-thermal fog)	0.06	–	–	–

[a] 24(c) Special Local Needs Label for the control of spotted wing drosophila in FL, GA, MA, MI, NC, and NJ.

[b] Use of malathion on cotton for the control of boll weevils is still supported in a supplemental label for Fyfanon ULV AG.
[c] Site cannot be re-treated more than three times in any one week.

Appendix B
Estimation of Terrestrial Invertebrate DT50

Table B-1 Malathion residues and DT50s on terrestrial arthropods

Crop	*Location*	*Nominal App. Rate 1 (lb ai/A)*	*Nominal App. Rate 2 (lb ai/A)*	*Sample Type*	*Plot*	*DAFA (DALA) [a]*	*Residue (mg ai/kg)*	*LN (residue) (mg ai/kg)*	*Slope*	*DT50 (d)*	*Reference [MRID]*
Apple orchard	Germany	1.61	—	Crop-dwelling	1	0	9.4	2.24	-0.00617	4.68	Knäbe, 2004 [46525902]
						1	2	0.693			
						2	1	0.00			
						4	0.7	-0.357			
						8	0.18	-1.71			
						16	0.48	-0.734			
						27	0.04	-3.22			
Apple orchard	Germany	1.61	—	Ground-dwelling	1	1	0.85	-0.16	-0.0125	2.30	Knäbe, 2004 [46525902]
						2	0.35	-1.05			
						3	0.14	-1.97			
						4	0.15	-1.90			
						8	0.03	-3.51			
						16	<LOQ[b]	-5.04			
						24	<LOQ[d]	—			
Alfalfa	Albacete, Spain	1.32	—	Ground-dwelling	1	1	0.09	-2.41	-0.508	1.36	Hanebeck and Staedtler, 2011 [49086411]
					2	1	0.46	-0.777			
					3	1	0.26	-1.35			
					1	2	0.05	-3.00			
					2	2	0.14	-1.97			
					3	2	0.06	-2.81			
					1	3	0.07	-2.66			
					2	3	0.06	-2.81			
					3	3	0.04	-3.22			
					1	4	0.05	-3.00			
					2	4	0.02	-3.91			

Table B-1 Malathion residues and DT50s on terrestrial arthropods

Crop	Location	Nominal App. Rate 1 (lb ai/A)	Nominal App. Rate 2 (lb ai/A)	Sample Type	Plot	DAFA (DALA) [a]	Residue (mg ai/kg)	LN (residue) (mg ai/kg)	Slope	DT50 (d)	Reference [MRID]
					3	4	0.03	-3.51			
					1	7	0.02	-3.91			
					2	7	<LOQ[b]	-5.04			
					3	7	ND[c]	-5.30			
					1	14	ND[d]	—			
					2	14	ND[d]	—			
					3	14	ND[d]	—			
					1	21	ND[d]	—			
					2	21	ND[d]	—			
					3	21	ND[d]	—			
Alfalfa	Albacete, Spain	1.32	—	Foliage-dwelling	1	0.167	0.48	-0.734	-0.634	1.09	Hanebeck and Staedtler, 2011 [49086411]
					2	0.167	1.33	0.285			
					3	0.167	3.34	1.21			
					1	1	0.5	-0.693			
					2	1	0.29	-1.24			
					3	1	0.41	-0.892			
					1	2	0.13	-2.04			
					2	2	0.1	-2.30			
					3	2	0.41	-0.892			
					1	3	0.06	-2.81			
					2	3	0.05	-3.00			
					3	3	0.09	-2.41			
					1	4	0.05	-3.00			
					2	4	0.01	-4.61			
					3	4	0.02	-3.91			

Table B-1 Malathion residues and DT50s on terrestrial arthropods											
Crop	***Location***	***Nominal App. Rate 1 (lb ai/A)***	***Nominal App. Rate 2 (lb ai/A)***	***Sample Type***	***Plot***	***DAFA (DALA) a***	***Residue (mg ai/kg)***	***LN (residue) (mg ai/kg)***	***Slope***	***DT50 (d)***	***Reference [MRID]***
					1	7	<LOQ[b]	-5.04			
					2	7	0.04	-3.22			
					3	7	0.02	-3.91			
					1	15	<LOQ[d]	—			
					2	15	<LOQ[d]	—			
					3	15	<LOQ[d]	—			
					1	21	<LOQ[d]	—			
					2	21	ND[d]	—			
					3	21	ND[d]	—			
Oilseed rape	Germany	0.714	—	Foliage-dwellers	1	0.167	5.14	1.64	-0.716	0.968	Staedtler, 2011 [49086410]
					2	0.167	5.28	1.66			
					3	0.167	12.91	2.56			
					1	1	1.99	0.688			
					2	1	2.22	0.798			
					3	1	6.24	1.83			
					1	2	0.57	-0.562			
					1	4	0.13	-2.04			
					2	4	0.07	-2.66			
					3	4	0.04	-3.22			
					1	5	0.05	-3.00			
					2	5	0.07	-2.66			
					3	5	0.14	-1.97			
					1	7	0.02	-3.91			
					2	7	0.13	-2.04			
					3	7	0.25	-1.39			

Table B-1 Malathion residues and DT50s on terrestrial arthropods

Crop	Location	Nominal App. Rate 1 (lb ai/A)	Nominal App. Rate 2 (lb ai/A)	Sample Type	Plot	DAFA (DALA) [a]	Residue (mg ai/kg)	LN (residue) (mg ai/kg)	Slope	DT50 (d)	Reference [MRID]
Oilseed rape	Germany	0.714	0.714	Foliage-dwellers	1	8 (0.229)	4.61	1.53	-0.209	3.32	Staedtler, 2011 [49086410
					2	8 (0.229)	5.46	1.70			
					3	8 (0.229)	2.48	0.908			
					1	9 (1)	1.46	0.378			
					2	9 (1)	3.51	1.26			
					3	9 (1)	1.51	0.412			
					1	10 (2)	1.14	0.131			
					2	10 (2)	0.52	-0.654			
					3	10 (2)	0.87	-0.139			
					1	11 (3)	0.6	-0.511			
					2	11 (3)	0.61	-0.494			
					3	11 (3)	0.65	-0.431			
					1	13 (5)	0.18	-1.71			
					2	13 (5)	0.34	-1.08			
					3	13 (5)	0.28	-1.27			
					1	15 (7)	0.07	-2.66			
					2	15 (7)	0.28	-1.27			
					3	15 (7)	0.18	-1.71			
					1	22 (14)	0.08	-2.53			
					2	22 (14)	0.06	-2.81			
					3	22 (14)	0.02	-3.91			
					1	29 (21)	0.04	-3.22			
					2	29 (21)	0.05	-3.00			
					3	29 (21)	0.03	-3.51			
	Germany	0.714	—		1	1	0.43	-0.844	-0.572	1.21	

Table B-1 Malathion residues and DT50s on terrestrial arthropods

Crop	Location	Nominal App. Rate 1 (lb ai/A)	Nominal App. Rate 2 (lb ai/A)	Sample Type	Plot	DAFA (DALA) [a]	Residue (mg ai/kg)	LN (residue) (mg ai/kg)	Slope	DT50 (d)	Reference [MRID]
Oilseed rape				Ground-dwellers	2	1	0.19	-1.66			Staedtler, 2011 [49086410
					3	1	0.88	-0.128			
					1	2	1.58	0.457			
					2	2	0.23	-1.47			
					3	2	0.32	-1.14			
					1	3	0.28	-1.27			
					2	3	0.08	-2.53			
					3	3	0.04	-3.22			
					1	4	1.94	0.663			
					2	4	0.45	-0.799			
					3	4	0.06	-2.81			
					1	5	0.23	-1.47			
					2	5	0.05	-3.00			
					3	5	0.09	-2.41			
					1	7	0.02	-3.91			
					2	7	<LOQ[b]	-5.04			
					3	7	0.01	-4.61			
Oilseed rape	Germany	0.714	0.714	Ground-dwellers	1	9 (1)	0.6	-0.511	-0.211	3.28	Staedtler, 2011 [49086410
					2	9 (1)	0.47	-0.755			
					3	9 (1)	0.43	-0.844			
					1	10 (2)	0.85	-0.163			
					2	10 (2)	0.24	-1.43			
					3	10 (2)	0.08	-2.53			
					1	11 (3)	0.52	-0.654			
					2	11 (3)	0.24	-1.43			

Table B-1 Malathion residues and DT50s on terrestrial arthropods

Crop	*Location*	*Nominal App. Rate 1 (lb ai/A)*	*Nominal App. Rate 2 (lb ai/A)*	*Sample Type*	*Plot*	*DAFA (DALA) [a]*	*Residue (mg ai/kg)*	*LN (residue) (mg ai/kg)*	*Slope*	*DT50 (d)*	*Reference [MRID]*
					3	11 (3)	0.04	-3.22			
					1	13 (5)	0.27	-1.31			
					2	13 (5)	0.1	-2.30			
					3	13 (5)	<LOQ[b]	-5.04			
					1	15 (7)	0.18	-1.71			
					2	15 (7)	0.05	-3.00			
					3	15 (7)	<LOQ[b]	-5.04			
					1	22 (14)	0.01	-4.61			
					2	22 (14)	0.01	-4.61			
					3	22 (14)	ND[c]	-5.30			
					1	29 (21)	0.01	-4.61			
					2	29 (21)	<LOQ[b]	-5.04			
					3	29 (21)	ND[c]	-5.30			